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IGR TRANSLITERATION OF RUSSIAN

The AGI Translation Office has adopted the Cyrillic transliteration recommended by the U. S. Department of the Interior, Board on Geographic Names, Washington, D. C.

NOTES:

- (1) "ye" initially, after vowels, and after *ъ, ь* ;
"e" elsewhere; when written as "ë"
in Russian, transliterate as "yë" or
"ë".

Well-known place and personal names that have wide acceptance will be used. Some translations may include elements of previous German transliteration from the Russian; this occurs in IGR most commonly in maps and lists of references. The reader's attention is called to the following variations between German and English systems which may cause confusion when trying to check back to original Russian sources.

Alphabet	transliteration	
А	а	a
Б	б	b
В	в	v
Г	г	g
Д	д	d
Е	е	e, ye ⁽¹⁾
Ё	ё	ë, yë
Ж	ж	zh
З	з	z
И	и	i
Й	й	y
К	к	k
Л	л	l
М	м	m
Н	н	n
О	о	o
П	п	p
Р	р	r
С	с	s
Т	т	t
У	у	u
Ф	ф	f
Х	х	kh
Ц	ц	ts
Ч	ч	ch
Ш	ш	sh
Щ	щ	shch
Ъ	ъ	"
Ы	ы	y
Ь	ь	'
Э	э	e
Ю	ю	yu
Я	я	ya

German	English
w	v
s	z
ch	kh
tz	ts
tsch	ch
sch	sh
schtsch	shch
ja	ya
ju	yu

RECENT STUDIES OF THE PALEOZOIC GROUP OF JAPAN¹

by

Haruyoshi Fujimoto

translated by Reiko Fusejima

ABSTRACT

The history and research on the Paleozoic formations in Japan is summarized.

In the past the Japanese Paleozoic was dealt with as one system under the general name Chichibu Paleozoic, as the Chichibu system in the Kantō region was thought to represent all Paleozoic formations in Japan. However, since the discovery of Lower Carboniferous fossils by Ichiro Hayasaka in 1924, Upper Devonian fossils by Mitsuo Noda in 1934 and Gotlandian fossils by Yoshio Onuki in 1937, the distribution and stratigraphic sequence of the Japanese Paleozoic have become better known.

The Hida metamorphic rocks constitute the basement of Paleozoic sedimentary basins and are assigned to pre-Gotlandian age.

The Gotlandian system is found in regions of complex geologic structure. Its distribution, though sporadic, may bear an important significance in view of structural geology. It consists predominantly of fossiliferous limestone, associated with shale, slate, phyllite and tuff.

* Distribution of the Devonian system is limited. It consists of sandstone, shale and slate, accompanied by tuff and limestone lenses. Conglomerate of schistose pebbles is locally found. The system may be conformable with the underlying Gotlandian system.

The carboniferous system is widely distributed, usually associated with the Permian, and consists chiefly of sandstone, shale, slate and schalstein, but is locally represented by limestone facies. The Carboniferous is generally unconformable with the Permian, although locally it may be conformable.

The Permian system has the widest distribution, amounting to nearly 80 percent of the known Paleozoic, hence its stratigraphic succession, fossil horizons and sedimentary facies are fairly well known. However, varied names now in use for the respective series require unification. The system consists of sandstone, shale, slate, schalstein, chert, often accompanied by limestone and conglomerate. Existence of conglomerate is one of the characteristics of the Permian system, although the constituent pebbles vary regionally and further study is needed to clarify the distribution, stratigraphic position and lithology of the conglomerates.

According to Hisakatsu Yabe, the name Chichibu system should be used only for the Carboniferous and Permian and a new name Kitakami system be used to denote the Gotlandian and Devonian.

Major orogenic movements of the Japanese Paleozoic are, 1) Akiyoshi orogenesis, 2) Setamai fold, 3) Shimizu fold, 4) Kesen fold and 5) Hida orogenesis. --Reiko Fusejima.

* * *

INTRODUCTION

The Paleozoic group of Japan has been generally known by the name Chichibu system or Chichibu Paleozoic. As it is widely distributed and constitutes the greater portion of mountainous regions, importance has been attached to the Paleozoic group which is considered the basement of the Japanese Islands. It was previously

assigned to Upper Carboniferous or Permian age, until 1924 when Ichiro Hayasaka reported occurrence of the Lower Carboniferous system, on the basis of the fossils he discovered in Oumi of Niigata Prefecture. Since then beds belonging to Lower Carboniferous were found one after another in various parts of Japan. In 1934, Mitsuo Noda collected Upper Devonian fossils at Tobigamori of Nagasaka-mura, Higashi-iwai-gun, Iwate Prefecture. Then in 1937 Yoshio Onuki found Gotlandian and Devonian fossils in the vicinity of Hikoroichi of Ofunato City, Iwate Prefecture, which reminded us of the Gotlandian fossils discovered at Kyomi'po of Korea in 1933 by Kin'emon Ozaki. The above discoveries by Hayasaka, Ozaki, Noda, Onuki, and others were

¹Translated from the Japanese: in the Journal of the Geological Society of Japan, v. 65, no. 766, p. 406-411, 1959. (Presidential address at the 66th Annual Meeting of the Geological Society of Japan).

epoch-making achievements, having markedly advanced the study of Japan's geologic history.

Afterwards, our knowledge of the Japanese Paleozoic has been supplemented by many facts as the number of investigators increased. Especially for the last ten years frequent debates on the Paleozoic group were held taking the opportunity of annual assembly of the Geological Society of Japan, gaining in noticeable results of study. Thinking of the days thirty-five years ago when Hayasaka made his report on the Oumi Paleozoic, the present progress of research on the Paleozoic group of Japan is almost unbelievable. I would like to retrospect these thirty-five years and review major research works accomplished and important problems discussed during the period, which may contribute to our future study.

RESEARCH ON BASEMENT ROCKS

Our knowledge of the basement of Paleozoic sedimentary basins has been poor, but the recent studies of the Hida metamorphic rocks have disclosed some facts. Assisted by many collaborators I have occupied myself with the research of the Hida metamorphic rocks. As the research is still under way, views on important problems vary with investigators. My view, which was reported previously (1957), is summarized herein.

1) The Hida Paleozoic zone is found on the outer side of the Hida metamorphic zone, bounded by the Median Dislocation Line, and the Gotlandian system occurs on the inner side of the Paleozoic zone.

The Naradani group is one of the members of the Gotlandian system. It consists of the Hayashinodaira formation in the upper section and the Hitotsunashi conglomeratic schist in the lower section. The Hayashinodaira formation yields *Favosites* and other fossils that indicate Gotlandian age. The Hitotsunashi conglomeratic schist is characterized by abundant pebbles (or pebbly blocks) that scatter in the green schist matrix. The pebbles can be classified into two types, A and B, by their shapes. Pebbles of type A are globular, ellipsoidal or discus, and are more or less deformed, while those belonging to type B are veinlike. Judging from the size and kind, the pebbles of type A are probably of an aquatic origin and the type B pebbles are supposedly derivatives of dike rocks. The pebbles of equatic origin are thought to have been supplied from the Mugishima granite and the Hida metamorphic rocks, so I concluded that the Mugishima granite and the Hida metamorphic rocks are pre-Gotlandian in age.

2) The Hida Paleozoic zone comprises the Gotlandian, the Devonian, the Carboniferous and the Permian systems. The first three systems are distributed in limited areas along the inner

margin of the Paleozoic zone. The Permian system near the inner margin of the Paleozoic zone is relatively thin and shows a neritic facies, although the facies becomes somewhat oceanic as the distance from the margin increases. These facts suggest that when the Paleozoic beds were being deposited in the geosyncline the Hida metamorphic zone to the north had already existed as a geanticline, and this favors the pre-Gotlandian theory for the Hida metamorphic rocks.

3) Petrologic and structural studies of the Hida metamorphic rocks have also disclosed many facts in favor of the pre-Gotlandian theory.

Thus, I am convinced that the Hida metamorphics are pre-Gotlandian in age.

The Motai group of the Kitakami massif and the Matsugadaira group of the Abukuma massif may constitute part of the basement rocks. The Motai group, reported by Koichi Tachibana (1952) for the first time, is thought to unconformably underlie the Upper Devonian Tobigamori formation (Nakakura formation). The group consists chiefly of green schist accompanied by quartzite. The Natsuyama conglomerates in the Tobigamori formation deserves attention as it contains pebbles of crystalline schists such as amphibole schist and epidote-chlorite schist. The Matsugadaira formation was reported by Toshihiko Sato (1956) and is thought to lie unconformably under the Upper Devonian Ainosawa formation. It consists of green phyllite and schistose sandstone. Both Motai group and Matsugadaira formations are certainly older than Upper Devonian, but their relations with the other metamorphic rocks are unknown, hence whether or not their distribution is significant can be known only through future study.

GOTLANDIAN SYSTEM

In 1937 Yoshio Onuki discovered Gotlandian and Devonian systems in the vicinity of Hiko-roichi, Ofunato City, and later Toshiro Sugiyama (1940) studied the fossils from these beds. Since then, it has become known that the Gotlandian system is distributed in other districts than the Kitakami massif, such as,

Gifu Prefecture

Fukuji, Kamitakara-mura, Yoskiki-gun
Naradani, Kiyomi-mura, Ohno-gun

Fukui Prefecture

Ise, Kamianama-mura, Ohno-gun
Nagano, Shimoanama-mura, Ohno-gun
(Hakubado, Ohtani)

Wakayama Prefecture

South coast of Nabae, Hirokawa-machi,
Arita-gun (5 km southwest of Yuasa,
Yuasa-machi)

Tokushima Prefecture

Miyagadani, Tatsukawa-Suberidani, Katsuura-machi,

Katsuura-gun (south margin of the Katsuura basin)

Kochi Prefecture

Yokokura-yama, Ochi-machi, Takaoka-gun

Imose, Hidaka-mura, Takaoka-gun

Ehime Prefecture

Kubono, Kurosegawa-mura, Higashiuwagun (east and southwest of Mitaki-yama, Doiyoshino-zawa)

Okanaru, Nomura-machi, Higashiuwagun

Miyazaki Prefecture

Around Gion-yama, Kuraoka, Gokasemachi, Nishiusuki-gun

Kumamoto Prefecture

Northeast of the mouth of the Fukani River, Shimomatsukuma-mura, Yatsushiro-gun.

The Gotlandian system at the above localities has not been thoroughly studied as yet, but an outline of its geology and paleontology is as follows:

1) The system consists chiefly of limestones accompanied by shale, slate, phyllite, tuff and siliceous tuff, as typically represented by the Kawauchi group and the Takainari group in the Kitakami massif, the Fukuji group in the Hida massif, and the Gotlandian system of Yokokura-yama, Shikoku, and Gion-yama, Kyushu.

2) The limestone is fossiliferous, yielding *Stromatopora*, *Tabulata* (*Halysites*, *Favosites*, *Heliolites*, etc.), *Tetracoralla* and *Brachiopoda*. *Stromatopora* was studied by Toshio Sugiyama (1940), *Halysites* by Takashi Hamada (1958) and *Favosites* by Tadao Kamei (1955).

3) Distribution of the Gotlandian system is generally sporadic. The system is found in regions of intricate geologic structure and is usually in fault contact with other beds. Especially in the Hida massif the system is distributed at Fukuji, Naradani and Kamianama along the inner margin of the Hida Paleozoic and surround the Hida metamorphic region. The system in the Outer Zone of Southwest Japan is distributed, unlike that of the Hida massif, along the Kurosegawa tectonic zone and its extension. Occurring generally as lenses elongated in the east-west direction and locally associated with metamorphic rocks and igneous rocks, the Gotlandian system occupies a unique position in the geologic structure. Studies by Ichikawa, Yamashita, Suyari and Katto have revealed the existence of the Kurosegawa tectonic zone which can be traced, though discontinuously, in the so-called Chichibu com-

plex of the Outer Zone of Southwest Japan and is thought to bear an important significance in view of geologic structure.

4) Because of the sporadic distribution, paleontology of the Gotlandian system has been known little. However, the system yields cosmopolitan fossils such as *Halysites*, *Favosites* and *Heliolites*, and its greater portion belongs to Middle Gotlandian (Salopian). This suggests a transgression during the period of Middle Gotlandian.

DEVONIAN SYSTEM

Research on the Devonian system in Japan began with the study of the Tobigamori area, Nagasaka-mura, by Mitsuo Noda (1934). Yoshio Onuki reported the distribution of the system at Hikoroichi of Ofunato-shi and at Takamoriyama, Kamiarisu-mura, Kesen-gun. Later, the Devonian system at Tobigamori was studied by Koichi Tachibana (1952) and the one at Hikoroichi and Takamoriyama was studied by Masahiro Ohkubo (1949, 1950) and Yoshio Onuki (1956). Distribution of the system was confirmed also at Ainosawa of the Hida massif and at Fukuji of the Hida massif. *Brachiopods* collected at Ainosawa by Toshihiko Sato were studied by Hayasaka and Minato (1940) who identified *Sinospirifer* and other species. Sato is continuing his paleontologic study of the system at Ainosawa. From the Devonian system at Fukuji Igo collected trilobites including *Cheirurus* (*Crotalocephalus*) *japonicus* as identified by Kobayashi and Igo (1956), which verified the age of Middle Devonian.

The result of the research works is summarized below.

1) Distribution of the Devonian system is fragmental, with only four known localities.

2) The Devonian system consists of sandstone, shale and slate, accompanied by tuff (at Hikoroichi of the Kitakami massif and at Ainosawa of the Abukuma massif) and limestone lenses (at Hikoroichi of the Kitakami massif and at Fukuji of the Hida massif). The Devonian Tobigamori formation in Nagasaka-mura of the Kitakami massif is accompanied by conglomerate (Natsuyama conglomerate) which contains pebbles of amphibole-quartz schist, epidote-amphibole-quartz schist and epidote-chlorite schist. An interesting fact is that the Nakakura formation, corresponding to the Tobigamori formation, yields *Leptophloeum*, a land plant, in association with marine animal fossils. The Ohno formation in the Lower Devonian system in the Hikoroichi area, Kitakami massif, locally contains granite pebbles in the schalstein and the tuffaceous sandstone near the base. The Nakazato formation in the Middle Devonian system is also accompanied by conglomerate.

3) In the Hikoroichi region of the Kitakami massif are developed the beds assignable to Lower and Middle Devonian system. The Tobigamori formation and the Ainosawa formation are known to correspond to Upper Devonian and the Takaharayama formation corresponds to Middle Devonian.

4) The stratigraphic relation between the Devonian system and the Gotlandian system is known only in the Hikoroichi region of the Kitakami massif, where it is conformable (Sugiyama, 1941). At Fukuji of the Hida massif the two systems are in fault contact.

5) The Devonian system yields corals, brachiopods and trilobites that are being studied by Koichi Tachibana and Toshihiko Sato.

CARBONIFEROUS SYSTEM

Distribution of the Carboniferous system is widest next to the Permian. The system, occurring generally in association with the Permian system, has been reported from about thirty places, of them the following districts are of stratigraphic interest:

- 1) Kitakami massif; Hikoroichi-Setamai district and Hitokabe district.
- 2) Abukuma massif; Soma district and Hitachi district.
- 3) Southwestern part of the Ashio massif.
- 4) Kanto massif; Kannagawa district and the upper drainage area of the Nakatsu River.
- 5) Hida massif; Oumi district, Fukuji district, Honto-Arakigawa district, Ohara district and Kamianama district.
- 6) Chugoku; Atetsu district, Ohga district, Taishaku district and Akiyoshi district.
- 7) Shikoku; Kamodani district and Itatori-gawa district.
- 8) Kuma massif; Usuki district and Hikawa district.

Stratigraphic succession and fossils of the Carboniferous system have been studied well. To answer the questions presented at the International Congress on Carboniferous Stratigraphy and Geology, the Sub-Commission on Carboniferous Stratigraphy has been organized in Japan. The following division and fossil zones are the result of debates on the Carboniferous system presided by the Sub-Commission:

Division (All Series)	Fossil Zone
Hikawa	<u>Triticites</u>
Kuriki	<u>Fusulina</u>
Taishaku	<u>Fusulinella</u>
Kamitakara	<u>Profusulinella</u> <u>Millerella</u>
Onimaru	<u>Dibunophyllum</u>
Ohdaira	<u>Sugiyamaella</u>
Arisu	<u>Syringothyris</u>
Hikoroichi	<u>Kitakamithyris</u>

Important points as revealed by the past studies on the Carboniferous system are mentioned below.

1) Distribution of the Carboniferous system is country-wide. The system consists mainly of sandstone, shale, slate and schalstein, but is locally represented by limestone facies. Occasionally it is accompanied by conglomerate.

2) Fossils are abundant, especially in limestone, shale and slate. Predominant fossils are marine animals such as fusulines, corals, bryozoans, brachiopods, mollusks and trilobites. Fossils of marine algae have been reported lately. It is worthwhile to mention that a land plant fossil (Lephophloeum) was found from the lowermost bed of the Carboniferous system in the Nagasaka district of the Kitakami massif by Koichi Tachibana (1955). The fusuline, coral and brachiopod fossils have been described only partly and the rest await study.

3) The respective series as tabulated above will be briefly described. The lower section of the Carboniferous system, ranging from the Hikoroichi series to the Ohdaira series, is poorly developed, occurring only in the Kitakami massif, Abukuma massif and in the Oumi district of the Hida massif. The Onimaru series consisting chiefly of black limestone is found in the Kitakami massif, Abukuma massif, Ashio massif, Kanto massif, Hida massif, and in the Chugoku and Kyushu regions. It yields characteristic fossils such as Dibunophyllum, Yuanophyllum, Kueichouphyllum, Palaeosmia and Gigantoproudectus, by which it is correlated with the Yuanophyllum zone of South China and the Dibunophyllum zone of Europe. As the system in the Kitakami and Abukuma massifs rests unconformably on the older rocks, Masao Minato maintains the occurrence of the Onimaru transgression.

The Kamitakara series, former Nagaiwa series, consists of black limestone and schalstein. The study by Yoshio Onuki and Tataro Yamada (1955) revealed that the series corresponds to the Millerella and Profusulinella zones. Hisayoshi Igo (1956) proposed the name Kamitakara

series instead of the Nagaiwa series. The series is typically represented by the lower section of the Ichinotani group at Fukuji. Corresponding beds are distributed in the districts of Atetsu, Taishaku and Akiyoshi, yielding *Millerella*, *Profusulinella*, *Lithostrotionella*, *Diphyphyllum*, *Thysanophyllum*, *Sciophyllum* and *Chaetetes*. This fossil fauna resembles that of the Pen-ch'i series of North China and Moscovian of the Urals.

The Taishaku series, corresponding to the *Fusulinella* zone, is typically developed in the Taishaku district. It abounds in *Fusulinella*, accompanied by *Ozawainella*, *Staffella*, *Eoschubertella* and *Fusiella*. *Amygdalophyllum*, *Taishakuphyllum rostrifer*, *Lonsdaleia yokomizoi* and *Pseudofavona taishakuana* are also found. Beds correlatable with the Taishaku series are widely distributed, as exemplified by the lower section of the Ishifune group in group in the Kanto massif, C₂ of the Oumi limestone, and middle section of the Ichinotani group, the Youno group in the Imajo district, bed IV in the Atetsu district, C_m β in the Akiyoshi district, the Itatorigawa group and the Amatsuki group.

The Kuriki series was named by Kametoshi Kanmera (1952) with the Kuriki formation of the Yamadake limestone beds, Kyushu, as the type. The Kuriki series is characterized by *Fusulina ohtanii*, *F. higoensis*, *Staffella pseudo-spherioidea* and *Fusulinella gracilis*. Corresponding beds are the Ishifune formation in the Kanto massif and the middle Ichinotani formation in the Hida massif.

The Hikawa series was named by Kanmera (1952) on the basis of the *Triticites* zone of the Yamadake limestone beds. Important index fossils are *Triticites matumotoi* Kanmera, *T. yayamadakensis* and *Quasifusulina longissima*. The upper part of the Ishifune formation, C₃ of the Oumi limestone, the uppermost part of the Ichinotani group and the Ohara formation belong to the Hikawa series.

4) The stratigraphic relation between the Carboniferous system and the Devonian system is known only in the Hikoroichi-Setami district and Nagasaka district of the Kitakami massif and

in the Soma district of the Abukuma massif. In the Hikoroichi-Setami district, Masahiro Ohkubo (1951) confirmed an angular unconformity and maintained that the Kesen fold took place between the two systems. The relation in Nagasakamura is, according to Koichi Tachibana, rather conformable. According to Toshihiko Sato, the Mano formation corresponding to the Hikoroichi series may be unconformable with the Upper Devonian Ainosawa series. At the base of the Onimaru series in the Kitakami massif is found a remarkable unconformity reported by Masao Minato. It is confirmed also in the Abukuma massif. Minato called this unconformity the Shimizu fold.

PERMIAN SYSTEM

Of all the Paleozoic formations in Japan the Permian system is the commonest member. Hence, its stratigraphy, fossil zones, sedimentary facies and paleontology have been studied well and discussed at annual meetings of the Geological Society of Japan. At the 1956 meeting Rokuro Morikawa proposed a standard stratigraphic division of the Japanese Permian system. As compared with the previous division in the Kitakami massif and the standard division which was proposed by Ryuzo Toriyama at the 1957 Pan-Pacific Science Congress, names of the respective series by Moriyama differ from those in other divisions excepting the Nabeyama series which is common with Toriyama's. Morikawa must have his own reason, but I hope the names would be unified as soon as possible through deliberation. The divisions are listed below with with fossil zones that are generally accepted.

The past results of research on the Permian system are summarized herein.

1) The distribution of the Permian system is extensive, and the constituent rocks are variable. Predominant rocks are sandstone, shale, slate, schalstein and chert, accompanied by limestone and conglomerate. The limestone is mostly grayish white and massive, although a dark gray stratified variety is occasionally found. Dolomite or dolomitic limestone also occurs locally. The stratigraphic position of the dolomite has not been defined as yet but is

Kitakami Massif	Toriyama's Division (All Series)	Morikawa's Division	Fossil Zone
Toyoma	Kuma	Akasaka	<u>Lepidolina</u> <u>Yabeina</u>
Kanokura	Akasaka	Akiyoshi	<u>Neoschwagerina</u>
	Nabeyama	Nabeyama	<u>Parafusulina</u> <u>Pseudofusulina</u>
Sakamotozawa	Sakamotozawa	Okumyogata	<u>Pseudo-</u> <u>schwagerina</u>

probably assignable to Middle Permian comprising *Parafusulina* zone and *Neoschwagerina* zone. Marked development of cherts is characteristic of the Permian system. A red variety is associated with manganese ore.

The Permian system often contains conglomerate. A most noticeable example is the Usuginu conglomerate of the Kitakami massif. It characteristically abounds in granite pebbles. Views are diversified on the stratigraphic position and mode of occurrence of the conglomerate. Conglomerates similar to the Usuginu conglomerate are known in the Abukuma massif and the Hida massif.

There is another conglomerate, Yasuba conglomerate, which was first reported from Shikoku by Toriyama. It characteristically consists of limestone pebbles. Recent survey has revealed equivalent conglomerates in the Chugoku region and the Kanto massif. Distribution, stratigraphy, mode of occurrence and lithology of these conglomerates require further study.

2) The limestone and shale abound in fusulines, corals, brachiopods, cephalopods, pelecypods, gastropods and trilobites. Most predominant fossils are fusulinids, on the basis of which the fossil zones are established and accurate correlation can be made. Rokuro Morikawa (1953), Ryuzo Toriyama (1958), Kametoshi Kanmera (1952) and many others studied fusulinids, but other fossils have been studied little.

3) Characteristics of the respective fossil zones are as follows:

Pseudoschwagerina zone. The type of this zone is found in the Okumiyogata formation of the Hida massif. The zone is known also in the Samegai formation south of Ibuki-yama, the Ueno formation in the Soma district, the lower Sakamotozawa series of the Kitakami massif, the upper part of the Tobishi group of the Kuma massif, and in Pl_1^{β} of the Akiyoshidai limestone of Akiyoshidai. The lower section of this zone abundantly contains *Pseudoschwagerina orientale*, associated with *Triticites kawanoboriensis*, *T. subnathorsti*, *T. plummeri*, *T. uddeni* and *T. cullomensis*, and the upper section yields *Pseudoschwagerina uddeni* with *Pseudofusulina vulgaris*, *P. krotowi*, *P. krafftii*, *Minojaponella eleongata* and *Acervoschwagerina fujimotoi*.

Parafusulina zone. The Nabeyama limestone of the Ashio massif is the type of this zone. Other examples are Pl_1^{δ} - Pm_1^{α} of the Akiyoshi limestone, the Fujiwaradake limestone, and the upper Sakamotozawa series of the Kitakami massif. The lower section characteristically contains *Schwagerina yabei* (Hanzawa) and *Parafusulina yabei* Hanzawa, accompanied by *Parafusulina rothi* and *P. splendens*. Species characteristic to the upper section are *Schwagerina japonica* and *S. ambigua*. *Para-*

fusulina kattaensis and *P. kaerimizuensis* are common between the upper and lower sections. I rather think that this zone is locally represented by *Pseudofusulina*, *Acervoschwagerina* and *Schwagerina*, instead of *Parafusulina*, as is exemplified by the Ibukiyama limestone, the Ousakatoge formation of Shima, the Funabashi formation, and the Ryogami group of the Kanto massif.

Parafusulina range seems to overlap the range of *Neoschwagerina*. Hence, if we strictly define the range of *Parafusulina* zone between the appearance of *Parafusulina* and the appearance of *Neoschwagerina*, the *Parafusulina* zone would become extremely thin or be replaced by *Neoschwagerina* zone, examples of such being known in the Niugawa group, and in the Kitakami massif. This was pointed out by Kanmera.

Neoschwagerina zone. Pm_2^{α} of the Akiyoshidai limestone is the type of this zone. The zone is known to occur in various parts of Japan, namely, the Ippaimizu formation of the Taishaku district, the Kurakaketoge formation of Fujiwaradake, the upper section of the Ibukiyama limestone, the upper section of the Akasaka limestone, the upper Okuzumi formation of the Hida massif, the Kaisho formation, P_2 of the Oumi limestone, the upper Manba formation, and the Kanokura series of the Kitakami massif. The lower part of the *Neoschwagerina* zone is characterized by *Neoschwagerina craticulifera*, whereas the upper part characteristically contains *N. margaritae* and *N. minoensis*. The lower part often contains *Pseudofusulina*, *Schwagerina* and *Parafusulina*.

Yabeina zone. The lowermost part of the Akasaka limestone is the type of this zone. The zone is known also in the Kuma formation of the Kuma massif, the uppermost part, Pu_{α} , of the Akiyoshi limestone, the Aritoh formation in the Taishaku district, the uppermost part of the Manba formation of the Kanto massif, the Ohashi formation in the Soma district, and the upper Kanokura formation of the Kitakami massif. The lower section of this zone yields *Yabeina igoi*, *Y. shiraiwensis* and *Neoschwagerina margaritae*, and the upper section abundantly contains *Yabeina globosa*, *Y. katoi* and *Y. multiseptata*.

Lepidolina zone. This zone was established by Kanmera, by separating the upper part of the Yabeina zone. The upper Kuma formation is the type. Characteristic species are *Lepidolina multiseptata*, *L. toriyamai* and *L. kumaensis*. Keiui Nakazawa and others have lately reported *Lepidolina* zone yielding *L. kumaensis* and *L. toriyamai* in the uppermost part of the Permian system in the Maizura district.

Thus, the fossil zones generally abound in fusulinids and consist chiefly of limestone. However, there are some beds abounding in

brachiopods and mollusks where limestone is rather scarce. According to Masao Minato, the *Neoschwagerina* zone in the Kitakami massif is represented by Brachiopoda and Mollusca, as exemplified by the lower Kanokura series.

4) The stratigraphic relation between the Permian system and the Carboniferous system was studied by many people. Absence of *Triticites* zone beneath the base of the Permian system was first noticed by Shoshiro Hanzawa (1941). Then, Masao Minato (1942) recognized a marked unconformity between the Carboniferous system and the base of the Permian system in the Kitakami massif and named the orogenic movement the Setamai fold. Since 1951 when Fujimoto and Kawada found *Triticites* zone at Oumi of Niigata Prefecture, equivalent zones have been reported from various parts of central Japan and Kyushu. Also it has become known that the unconformity discovered by Minato in the Kitakami massif extends to the Abukuma massif and as far as to the Chugoku region including the districts of Akiyoshi, Taishaku and Atetsu, while in some places the Carboniferous and Permian systems are conformable.

DIVISION OF JAPANESE PALEOZOIC

The Paleozoic of Japan was generally known by the name Chichibu system. However, as we now know that the Paleozoic comprises the systems ranging from Permian to Gotlandian, it is impossible to have the Chichibu system represent the whole Paleozoic. Hisakatsu Yabe (1959) advocated to use the name Chichibu system for Carboniferous and Permian and to give a new name Kitakami system to Gotlandian and Devonian. I agree with this pertinent proposal. Yabe subdivided the Chichibu system into lower, middle and upper parts, separating them by the unconformity beneath the Onimaru series and

one beneath the Sakamotozawa series.

PALEOZOIC CRUSTAL MOVEMENT

The Japanese Paleozoic has many unconformities which suggest orogenic movements. Most conspicuous movements are listed below:

- 1) Akiyoshi orogenesis, after the Akasaka series (Kuma series, Toyoma series).
- 2) Setamai fold, immediately before the Sakamotozawa series.
- 3) Shimizu fold, immediately before the Onimaru series.
- 4) Kesen fold, immediately before the Hikoroichi series.
- 5) Hida orogenesis, before the Naradani formation.

I have briefly mentioned about these movements excepting the Akiyoshi orogenesis. Study of the Akiyoshi orogenesis was commenced by Yoshiaki Ozawa (1923). Ozawa's study was an epoch-making contribution to geological research in Japan. The orogenesis was studied further and discussed by Toshio Sugiyama, Teiichi Kobayashi, Ryuzo Toriyama and Hisakatsu Yabe. Lately, Yoshiyuki Hasegawa has published his view opposing the previous views. The geologic structure of Akiyoshidai is the most fundamental and the most important problem of the geology of Japan, and its solution is a matter of urgent necessity. In order to reach a definite conclusion we must make daring attempts, such as drilling in appropriate sites and try new methods of study, which depend on you, members of this society.

SOVETSKAYA GEOLOGIYA (SOVIET GEOLOGY)

IN TRANSLATION, 1960, NUMBERS 4, 5, 6¹

CONTENTS, CRITIQUE, SELECTED PUBLICATION, AVAILABILITY OF TRANSLATIONS

The translation program of the American Geological Institute now includes complete translation of the journal *Sovetskaya Geologiya* (Soviet Geology), beginning with the 1960 volume year. Each issue is translated cover-to-cover. The translated papers are reviewed by members of the staff of the Geology Department of the Virginia Polytechnic Institute under an arrangement with Professor Byron N. Cooper, Chairman. Papers of greatest significance and most general interest undergo additional editing and are published in full in *International Geology Review*. All other papers not selected by the review group for publication in IGR are available as individual translations, reproduced in photocopy form from the translation manuscript.

The table of contents of translated issues of *Sovetskaya Geologiya* will be listed in this and subsequent issues of *International Geology Review*, showing author, title, original journal pagination, and reviewer's comments of each paper not selected for publication. Those papers appearing in IGR in full are designated by a star (★).

Orders for photocopies of translations not published in IGR should include the following information from the table of contents: Senior author, number of pages, price, and order reference number, i. e., "Nekrasov, 32 pp., \$4.80, Order ref:SG60-1-2." Payment must accompany order. Send to: Translations Office, American Geological Institute, 2101 Constitution Avenue, N. W., Washington 25, D. C.

Sovetskaya Geologiya (Soviet Geology)

April 1960, No. 4

CONTENTS AND TRANSLATION AVAILABILITY

Translation by Research International Assoc.

Voytkovich, G. V. and Belokryz, L. S., TRACES OF ANCIENT LIFE ON EARTH.

pp. 3-22

Photocopy 35pp. \$5.25, Order ref:SG60-4-1

This paper is a review of Precambrian fossil occurrences of the world with a brief section on the nature of the Precambrian atmosphere and on the time span of the Precambrian. Most of the occurrences cited are non-Russian. This paper adds little to our knowledge of Russian Precambrian fossils. It is not a particularly critical review of the non-Russian occurrences.

Popov, V. I., FUNDAMENTAL PRINCIPLES OF THE STUDY OF GEOLOGICAL FORMATIONS

pp. 23-39

Photocopy 27pp. \$4.05, Order ref:SG60-4-2

This contains an elaborate classification of rocks into genetic groups or associations on the basis of broad structural provinces such as oceanic marginal continental etc., broad tectonic setting and tectonic stage. Another classification breaks down the stages into facies suites based on climate mainly. The paper adds nothing to our knowledge of Russian geology. The various categories are not illustrated by references to specific stratigraphic sections, structural features, etc. except in a most casual way. This is painted with a very broad brush.

Milanovskiy, Ye. Ye., RECENT VOLCANISM AND ITS PLACE IN THE STRUCTURE AND HISTORY OF THE ALPINE GEOSYNCLINAL REGION OF THE SOUTHERN USSR

pp. 40-56

Photocopy 31pp. \$4.65, Order ref:SG60-4-3

According to their footnote, this was presented at the XXI International Geological Congress. It is a good synthesis of volcanic activities in a large region. I would place it in the "top-quarter" category with some reservations.

★Travin, A. B., ON CLASSIFICATION AND NOMENCLATURE OF COAL MICROCOMPONENTS NEEDED FOR TECHNOLOGICAL PURPOSES

pp. 57-65

IGR, v. 3, no. 11 (this issue)

Turgarinov, A. I., and Zmeenkov, A. V., ON THE SOURCE OF ORE MATTER DURING THE FORMATION OF ENDOGENOUS DEPOSITS

pp. 66-78

Photocopy 22pp. \$3.30, Order ref:SG60-4-4

SOVETSKAYA GEOLOGIYA

Compares data on various lead isotope ratios from Canada, Broken Hill, and the Krivoi Rog rocks in Russia. They find that much of lead suggests a mixture of the early lead and radiogenetic lead in many deposits (as do others). Also study distribution of uranium in skarn rocks and conclude uranium is removed by the hot solutions and is taken farther out into the country rock. They conclude that maybe the old idea of lateral secretion isn't so bad after all. Article needs considerable editing and smoothing out; either poorly written or poorly translated, probably writing.

okolov, I. P., THE FERGANA IODINE-BROMINE DISTRICT

pp. 79-84

Photocopy 10pp. \$1.50, Order ref:SG60-4-5

General descriptive information of iodine-bromine content of some formation waters in one geological region. Not definitive. Descriptive areal hydro-geochemistry with restricted sampling.

khailov, N. N., ON CONSTRUCTION OF STRUCTURAL PATTERNS FROM REGIONAL AEROMAGNETIC OBSERVATIONS

pp. 85-91

Photocopy 12pp. \$1.80, Order ref:SG60-4-6

This paper deals with a method of separation of different structural zones from aeromagnetic surveys. It does not indicate how the computations are done though it does mention how the information is used. The paper does not have a reference list and some of the terms used may be due to translation errors.

afonov, N. I., Polikarpochkin, V. V., and Trushkov, Yu.N., COMPLEX METHODS OF PROSPECTING FOR GOLD DEPOSITS

pp. 92-110

Photocopy 30pp. \$4.50, Order ref: SG60-4-7

Use of electric methods for finding quartz veins. Use what they call ultrasound location and ultrasound radioscapy, whatever these may be. Also use seismoelectric property for finding quartz veins and quartz cores in pegmatites (must be an introduction method). Much of the latter part is strictly a horse-sense type program of prospecting for different problems.

Short Notes

adchenko, G. P. and Rosenkrants, A. A., NEW DATA ON THE PERMIAN DEPOSITS OF THE NORTHEASTERN PART OF THE BALKHASH AREA

pp. 111-115

Photocopy 10pp. \$1.50, Order ref:SG60-4-8

New plant evidence moves a volcanic sequence out of the Carboniferous into the Permian.

amayev, N. F. and Chermeninova, I. V., ON THE AGE OF CERTAIN VOLCANIC STRATA AND ORE MANIFESTATIONS ON THE EASTERN SLOPE OF THE SOUTH URALS

pp. 115-118.

Photocopy 9pp. \$1.35, Order ref:SG60-4-9

Paper describes finding of evidence for some lower Paleozoic volcanics previously thought to be Silurian or Devonian and since the lower Paleozoic rocks have the ore deposits, new areas of potential deposits should be investigated. Good, short note, but of limited interest.

tom, G. I., ON THE GROWTH OF THE CONGLOMERATE-CLAYEY SERIES OF THE KERZHENETS, LINDA, VEDOMOST AND SERGA RIVER BASINS

pp. 118-120

Photocopy 7pp. \$1.05, Order ref:SG60-4-10

This paper reports on some interesting rocks with what are evidently contemporaneous folds.....Contains very general megascopic petrography descriptions, Triassic dating of sediments by ostracods, whose names are listed, and interpretation of general sedimentation and tectonic history.

Subbota, M. I., THE GAS GEYSER OF WESTERN TURKMENIA AND THE MECHANISM OF ITS ACTIVITY

pp. 120-123

IGR, v. 3, no. 11 (this issue)

etrosov, P. S., BASIC CHARACTERISTICS OF THE STRATIGRAPHY OF THE DEVONIAN DEPOSITS OF THE BARUM-KHURAY BASIN

pp. 123-127

Photocopy 9pp. \$1.35, Order ref:SG60-4-11

This paper describes a very thick, nearly complete Devonian section in western Mongolia. The section contains marine fossils at several levels and plants in the upper part. The upper part may be Viséan or Tournaisian in age. The rocks are clastic and volcanics. The great thickness and volcanic rich nature of this fossiliferous Devonian should make it interesting to many readers.

etrov, P. A., DISCOVERY OF GOLD MINERALIZATION IN SKARNS

pp. 128

Photocopy 2pp. \$0.30; Order ref:SG60-4-12

INTERNATIONAL GEOLOGY REVIEW

This paper reports on a rather unusual occurrence of gold, but is almost purely descriptive in the most rudimentary way. Not worthy of publication because of brevity and local nature of the mineralization reported.

Osipov, M. A., THE DOZMEINOGORSK GABBROID COMPLEX IN THE RUDNYY ALTAY
pp. 128-131 Photocopy 6pp. \$0.90, Order ref:SG60-4-13

Paper is too narrow in reader interest to be worthy of publication. It is largely descriptive.

Criticism and Review

Tokarev, L. V., THE PROBLEM OF LONG DISTANCE MIGRATION OF HYDROCARBONS
pp. 132-135 Photocopy 9pp. \$1.35, Order ref:SG60-4-14

Deals with a rather local problem. Needs better reference to work of V. Hassau in the U.S.

Rudich, K. N., STRATIGRAPHICAL DICTIONARY OF THE NORTHEAST U.S.S.R.
p. 135 Photocopy 1p. \$0.15, Order ref:SG60-4-15

Lexicon of Magadan stratigraphy announced.

Tikhomirov, V. V. and Voskresenskaya, N. A., FROM THE HISTORY OF THE GEOLOGICAL SCIENCES
pp. 136-139 Photocopy 10pp. \$1.50, Order ref:SG60-4-16

Divided opinion as to whether such information belongs in top category. Provides the reader with some knowledge of Russian and to some extent other European geologists of former times.

Scientific Notes and News

Shantser, Ye. V. and Lavrushin, Yu A., PLENARY SESSION OF THE PERMANENT COMMITTEE ON THE QUATERNARY SYSTEM UNDER THE INTERDEPARTMENTAL STRATIGRAPHIC COMMITTEE
pp. 140-154 Photocopy 42pp. \$6.30, Order ref:SG60-4-17

This paper reports on points of view and emerging ideas on the proper classification of the Pleistocene which will be of wide interest to geologists all over the world. However, the report takes 50 words to say what could be better said in 10 words and is the windiest paper this reviewer has read; note for example the resolution title, "Resolution of the joint plenary session of the Permanent Commission on the Quaternary System, under the Interdepartmental Stratigraphic Committee, the Commission on the Study of the Quaternary Period of the Academy of Sciences of the USSR and the Section of the National Committee of Geologists of the Geochronology and Climatology of the Quaternary Period, 13-16, February, 1959." Possibly someone could condense this from its present 42 pages into 20 or less and it might well be worth the trouble.

Sovetskaya Geologiya (Soviet Geology)

May 1960, No. 5

CONTENTS AND TRANSLATION AVAILABILITY

Translation by Royer and Roger, Inc.

Abdullaev, Kh. M., PETROMETALLOGENIC SERIES IN IGNEOUS ROCKS AND ENDOGENETIC ORE DEPOSITS
pp. 3-13 Photocopy 18pp. \$2.70, Order ref:SG60-5-1

A relatively good article on the interrelationships of ore deposits, magmatic activity, and tectonic distributions of both. This is a good review and the classification may be slightly different from others. Introduction is rather lengthy and wordy but statement of the petrometallogenetic series is not bad. Division is made into petrometallogenetic series related to geosynclines, geanticlines, marginal areas of platforms, and inner areas of platforms. Mississippi Valley types are omitted.

Kravchenko, V. M., VARIETIES OF RICH MARTITE ORES OCCURRING IN THE NORTHERN PART OF THE LAKSAGAN AREA IN KRIVOI ROG
pp. 14-31 Photocopy 28pp. \$4.20, Order ref:SG60-5-2

Largely a mineralography paper describing textures of iron minerals and various types of quartz. Says first are hard ferruginous sediments, then these are metamorphosed and silica rimmed; get magnetite, martite and jaspilite; third, supergene ore — latter caused by replacement of quartz by siderite, goethite, and lepidocrocite or leaching of these same minerals plus quartz to get so-called "compact ore." Sounds like Lake Superior. Not good enough paper.

SOVETSKAYA GEOLOGIYA

- * Solovov, A.P. and Kunin, N. Ya., METALLOMETRIC SURVEYING IN MOUNTAINOUS AREAS BASED ON ALLUVIAL DEPOSITS

pp. 32-46

IGR, v. 3, no. 11 (this issue)

- Bulakh, A. G. and Abakumava, N. B., THE SEBL-YAVR MASSIF OF ULTRABASIC AND ALKALIC ROCKS AND CARBONATITES (KOLA PENINSULA)

pp. 47-60

Photocopy 24pp. \$3.60, Order ref:SG60-5-3

This is part of the "classic" Kola peninsula area.

- Kurshakova, L. D., RELATIONSHIP BETWEEN VEIN ROCKS, PYRITIC ORE AND OVERLYING ROCK AT THE BURIBAY ORE DEPOSIT

pp. 61-73

Photocopy 22pp. \$3.30, Order ref:SG60-5-4

An account of pyrite ore in volcanic rocks with reference to data proving separate ages of mineralization. Uses F. C. Smith's pyrite "geothermometer" method to prove disseminated ore is of different age than vein ore. Not a bad paper but narrow in scope.

- * Teodorovich, G. I., ON THE ORIGIN OF SEDIMENTARY DOLOMITES

pp. 74-87

IGR, v. 3, no. 5, pp. 373-384

- Sultanov, A. D., Ismaylov, K. A. and Tairov, Ch. A., THE SUBDIVISION OF UPPER CRETACEOUS ROCKS OF THE DEBRAR FLYSCH ZONE

pp. 88-96

Photocopy 15pp. \$2.25, Order ref:SG60-5-5

This is a stratigraphic study in the southeastern Caucasus in which European stages are recognized mainly on the basis of foraminiferal faunas. The stages are related to the local lithologic units and the distinctive minerals of the latter are noted. No fossil plates. This sort of report is of greatest interest to other stratigraphers working in and near the area covered, not to the general reader.

- * Koshlyak, V. A., THERMAL PROPERTIES OF MESOZOIC AND CENOZOIC SEDIMENTS IN THE EASTERN PART OF THE WEST SIBERIAN LOWLAND

pp. 97-106

IGR, v. 3, no. 11 (this issue)

Short Notes

- * Bykovskaya, Ye. V., Polyevaya, N. I. and Podgornaya, N. S., ABSOLUTE AGE OF MESOZOIC AND CENOZOIC VOLCANIC AND INTRUSIVE ROCKS IN THE OLGA-TETYUKHINO AREA

pp. 107-114

IGR, v. 3, no. 11 (this issue)

- Mel'nichuk, V. A. and Bulkin, G. A., OCCURRENCE OF MERCURY ORE IN PRIVETNOYE VILLAGE AREA IN THE CRIMEA

pp. 114-115

Photocopy 5pp. \$0.75, Order ref:SG60-5-6

Describes tiny veinlets of epithermal type with a paragenetic sequence of quartz, alushtite-cinnabar, and quartz, galena, sphalerite, chalcopryrite, and dickite. Represent separate stages of mineralization.

- Rakcheyev, A. D., DISCOVERY OF FOSSIL REMAINS OF FISHES, ARTHRODIRES, AND CROSSOPTERYGIANS IN THE KARABASH AREA AND THE AGE OF THE KARABASH ORE DEPOSITS

pp. 116-117

Photocopy 5pp. \$0.75, Order ref:SG-60-5-7

Describes the changes in stratigraphy of the Karabash area in the folded and overthrust Urals. Fossils indicate rocks are younger than previously thought and hence mineralization is post-Givetian age. Deposits of pyrite and chalcopryrite may be more widespread therefore. Local interest.

- Drushchits, Yu. G., NEW DATA ON THE STRATIGRAPHY OF TERTIARY DEPOSITS IN THE PALONA DISTRICT OF KAMCHATKA

pp. 118-122

Photocopy 11pp. \$1.65, Order ref:SG60-5-8

Actually a stratigraphy and paleontology paper and not ore deposits. Concerns the local "relative" problems of stratigraphy in the area near the Sea of Okhotsk. Paper is poorly translated and of narrow scope except for someone specializing in the Tertiary.

Review and Discussion

- Reply to a review of V. N. Florovskaya's book, LUMINESCENCE-BITUMINOLOGIC METHOD AND ITS APPLICATION IN PETROLEUM GEOLOGY, written by P. F. Andreyev, Ye. M. Geller, A. A. Khartsev and Z. M. Tabasaranskiy

pp. 123-127

Photocopy 12pp. \$1.80, Order ref:SG60-5-9

INTERNATIONAL GEOLOGY REVIEW

It would seem that this critical reply to the reviewers unfavorable comments is very much in order. However, the article needs editorial polish, preferably by an expert on bituminous luminescence.

In the Ministry of Geology

PRESENT STATUS AND PLAN FOR FURTHER DEVELOPMENT OF EXPLORATORY DRILLING OPERATIONS

pp. 128-129

Photocopy 5pp. \$0.75, Order ref:SG60-5-10

A progress report of exploration drilling and plans for further development of exploration drilling. Of limited value and does not contain any information of any consequence.

THE ESTIMATED EVALUATION OF MINERAL RESERVES

pp. 129-130

Photocopy 2pp. \$0.30, Order ref:SG60-5-11

Scientific Notes and News

Pustovalov, L. V. and Pavlovsky, Ye. V., THE FOURTH SESSION OF THE INTERNATIONAL ASSOCIATION FOR THE STUDY OF THE INTERIOR OF THE EARTH'S CRUST IN WESTERN GERMANY

pp. 131-135

Photocopy 12pp. \$1.80, Order ref:SG60-5-12

This is merely, as marked, a "scientific news note" concerning a field conference. There are much better and more complete accounts of the areas visited in the already existing literature by men who actually studies the areas (and in some cases were the guides on this trip).

PROGRESS CONFERENCE ON PRINCIPLES OF PERIODIZATION AND STRATIGRAPHY OF THE PALEOLITHIC PERIOD IN EASTERN EUROPE

pp. 135-137

Photocopy 8pp. \$1.20, Order ref:SG60-5-13

This report embodying a lengthy resolution is wordy, windy and lacks substance. The resolution does little more than point up Soviet deficiencies in geological study of Paleolithic cultures and a resolve to correct this deficiency.

PAVEL VASIL'YEVICH TURBANOV (1905-1960)

p. 138

Photocopy 3pp. \$0.45, Order ref:SG60-5-14

This obituary is needlessly long and contains a Red flavor that has no place in a scientific journal.

Sovetskaya Geologiya (Soviet Geology)

June 1960, No. 6

CONTENTS AND TRANSLATIONS AVAILABILITY Translation by Research International Associates

*Suloyev, A. I., MAGMATISM OF THE EASTERN SAYAN

pp. 3-25

IGR, v. 3, no. 11 (this issue)

Bilibina, T. V., METALLOGENY OF THE SOUTHERN PART OF THE URALS

pp. 26-40

Photocopy 25pp. \$3.75, Order ref:SG60-6-1

Describes tectonic set-up and Paleozoic folding shortly after or during sedimentation. Get different structures of different ages and also different intrusives. Area predominates in Cu, Cr, Ni, Co, and Fe. Not too bad of a review article. Translation needs editing.

Pukharev, A. I., AN ATTEMPT TO USE THE SPECIFIC FEATURES OF AN ASSOCIATED MINERALIZATION AS A GUIDE TO STRUCTURAL MINERALIZATION CONTROL

pp. 41-55

Photocopy 24pp. \$3.60, Order ref:SG60-6-2

This describes the distribution of tourmaline and to a less extent other skarn minerals as related to large magnetite deposits of a presumably contact-metasomatic type of deposit. Find clear relationships of zoning--laterally and vertically with respect to faults and other structural controls. Is a certain influence of wall rock and writers break things up into granulization stages, etc., but is probably all part of one cycle of metasomatism. A lot of good data. It is either very poorly written or more likely poorly written and also poorly translated.

Rossmann, G. I., PRIMARY DISPERSION OF METALS IN THE WALL ROCK OF THE NIKOLAYEV PYRITE POLYMETALLIC DEPOSIT (RUDNY ALTAI)

pp. 56-64

Photocopy 15pp. \$2.25, Order ref:SG60-6-3

SOVETSKAYA GEOLOGIYA

Good geochemical paper describing element distribution and trace metals around some Cu-Pb-Zn deposits. Good diagrams and tables. Finds haloes of Pb, Zn, Cu, Ba, Ag, B, Mo, As, Cd & Sb above are in surrounding country rock. In the halo of mineralization, Pb, Ba, Ag, Bi, & Sb are compared to inner aureole and Zn, Cu, & Mo to the outer zone. Says this is result of precipitation by a filtering process related to ionic size. Ore haloes related to faults (their quarry breaks) and rock types (permeability a factor). Good paper but needs good technical overhauling by geologist.

Rezanov, I. A., GEOLOGICAL INTERPRETATION OF SEISMIC SOUNDING OF THE BASEMENT COMPLEX
pp. 65-77 Photocopy 24pp. \$3.60, Order ref:SG60-6-4

This is a good paper and contains an excellent summary of data and its interpretation.

*Frolov, A. D., RADIO-WAVE METHOD OF GEOLOGICAL MAPPING
pp. 78-92 IGR, v. 3, no. 11 (this issue)

Dzhumagaliev, T. N., OUTLOOK FOR GAS AND OIL DISTRIBUTION BETWEEN THE URAL AND VOLGA RIVERS
pp. 93-104 Photocopy 19pp. \$2.85, Order ref:SG60-6-5

Good paper; needs edit by oil geologist.

Moshkin, V. N., NEW DATA ON THE PRECAMBRIAN STRATIGRAPHY OF THE UDA-ZEYA REGION
pp. 105-110 Photocopy 11pp. \$1.65, Order ref:SG60-6-6

A local (but large area) account of a thick section of high-grade, amphibolite facies-granulite facies-metamorphic rocks. Author uses mineral name adjective so much that can't tell really what is present. A local problem of a deep-seated terrain. Largely a discussion and tabulation type of paper, narrow in scope.

*Germanyuk, M. M., THERMAL WATERS OF THE PALEOZOIC AND MESOZOIC SEDIMENTS IN THE WESTERN PART OF THE CRIMEAN PENINSULA
pp. 111-118 IGR, v. 3, no. 11 (this issue)

*Mogilevskiy, G.A., EMPLOYMENT OF GAS LOGGING IN PROSPECTING OPERATIONS
pp. 119-128 IGR, v. 3, no. 11 (this issue)

Devdariani, A. S., CLASSIFICATION OF METHODS IN MEASURING THE INTENSITY OF GEOLOGIC PROCESSES FOR GEOLOGICAL ENGINEERING
pp. 129-131 Photocopy 6pp. \$0.90, Order ref:SG60-6-7

The paper by Devdariani deals with various methods of determining the removal of rock waste by all of the erosional agents and the rate of accumulation of sediments under various environments. The measurements are made by repeated observation and the use of maps, aerial photographs, etc. Most of the methods would fall under the standard procedures used in a sedimentation study.

Ponomarev, M. S., ABOUT THE TERMS "PSEUDO-SPECULARITE" AND "PSEUDO-LEPIDOMELANE"
pp. 131-132 Photocopy 4pp. \$0.60, Order ref:SG60-6-8

The author severely criticizes Semenenko and other authors for using the terms pseudo-specularite and pseudo-lepidomelane for material formed in and along thrusts (but still the above minerals). Very valid criticism. Good to see a "letter to the editor". Local interest.

Rüdich, K. N., ON "POST GRANITE" DIKES OF THE BERELEKHA RIVER BASIN (SOURCES OF THE RIVER KOLYMA)
pp. 132-134 Photocopy 6pp. \$0.90, Order ref:SG60-6-9

This article is purely descriptive and offers nothing new other than data about a certain region.

Galiev, U. Z., FAULTING IN THE PERMIAN ROCKS OF SOUTHEAST TATARIA
pp. 135-137 Photocopy 7pp. \$1.05, Order ref:SG60-6-10

Of intermediate interest.

*Bindeman, N. N., THE DETERMINATION OF GROUND-WATER DISCHARGE IN ALLUVIAL DEPOSITS
pp. 137-139 IGR, v. 3, no. 11 (this issue)

In the Ministry of Geology

ON GENERAL PERSPECTIVES IN THE DEVELOPMENT OF GEOLOGICAL WORK IN THE U.S.S.R.
pp. 140-146 Photocopy 20pp. \$3.00, Order ref:SG60-6-11

An interesting account of a review of Soviet geology in 1959-60. Heads of republics are

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brought in and interviewed as to developments in mineral resources. They have problems of coordination between mapping, geophysics, and exploration. Most interesting is a discussion of the geological "Campaigns". These are apparently prospecting groups, largely untrained, who go out in groups of 50 to 150 and in effect stake claims. In 1959 there were 90,000 people involved in these campaigns and more than half of these were in the Irkutsk Oblast. These staked 1,402 claims and about 1/5 of those checked out by the geological organizations were of interest. Includes a summary of things found by the Campaigns. Very interesting but considerable extraneous material.

Scientific Notes and News

1. SUMMARY OF SESSION ON COORDINATION OF MINERALOGENIC (METALLOGENETIC) RESEARCH, (by A. V. Grigoriev), 2: ON THE SESSION OF THE CONGRESS OF SCIENCE ON TECTONICS IN SIBERIA AND THE FAR EAST (by G. E. Ryabukhin), 3. THE GEOLOGICAL SERVICE OF GREAT BRITAIN
pp. 147-152 Photocopy 8pp. \$1.20, Order ref:SG60-6-12

Routine interest.

Review and Discussion

- Marinov, N. A., ON THE BOOK BY F. A. RUDENKO, "HYDROGEOLOGY OF THE UKRAINIAN CRYSTALLINE MASSIF"
pp. 153-156 Photocopy 8pp. \$1.20, Order ref:SG60-6-13

This article is a review and critique of a book of the hydrology of the Ukrainian crystalline massif. The book from the review covers the geology and ground-water characteristic of the crystalline rocks as well as the production and recharge characteristics. From the review it does not contain anything that can not be found in current hydrology books outside of the description of the local geological conditions.

- Voytkovich, G. V., SOME CRITICAL REMARKS ON THE ARTICLE OF YU. M. SHEYNNMANN, "THE MOST ANCIENT STRUCTURES OF PLATFORMS AND THEIR SIGNIFICANCE FOR GENERAL TECTONICS" pp. 156-159 Photocopy 10pp. \$1.50, Order ref:SG60-6-14

Nearly top-rank commentary.

- Volochkovich, K. L., ON THE ARTICLE OF V. I. FOMINSKIY, "NEW DATA ON THE STRATIGRAPHY OF THE ORDOVICIAN OF THE GORNÝ ALTAI (SOVETSKAYA GEOLOGIYA 1959, NO. 2)
pp. 160-161 Photocopy 5pp. \$0.75, Order ref:SG60-6-15

Routine interest.

ON CLASSIFICATION AND NOMENCLATURE OF COAL MICROCOMPONENTS FOR TECHNOLOGICAL PURPOSES¹

by

A.B. Travin

ABSTRACT

A new classification of coal microcomponents based on microscopic features observable in reflected light is suggested. Primary basis of classification is nature of the original matter, namely its botanical nature and degree of coalification; and secondly on the degree of primary oxidation. According to the degree of coalification ("gelification" of the writer) distinguishes non-gelified, partly gelified, and gelified substances; from the point of view of their botanic nature - woody, parenchyma and cortex tissues (also lipoids and algae) and, according to the degree of primary oxidation, four stages are indicated. In contrast to some existing classifications the writer does not recognize groups of gelified [anthraxylon?] and fusain microcomponents opposite to each other because he thinks that gelified components may later become fusained as well (as a result of oxidation). The writer underlines the importance of the microcomponents under consideration for practical purposes. --M. Russell.

* * *

A special conference of coal petrographers of the Soviet Union, which was held by IGI in 1956, was dedicated to the problem of working out a common nomenclature of microcomponents and a common method of determining the petrographic coal structure observed under the microscope in the reflected light. In spite of the importance and usefulness of this conference, it did not result in a classification and nomenclature of coal microcomponents to fully answer modern needs. This prompted the author to write the following paper.

The various qualities of coal: caking, coking, concentrating, presence of gas, tendency toward oxidation and self-combustion as well as silicate danger in mining, structure and outcrop of chemical products at half-coking, thermotechnical qualities, are basically determined by the petrographic structure and the degree of coal metamorphism.

The qualitative variety of coal depends upon the quantitative correlation between coal microcomponents. Coal, rich in cortical tissue and leaf parenchyma, especially of coniferous plants, is characterized by a higher content of hydrogen, outlet of volatile matters and thickness of the plastic layer compared with coal of the same metamorphism degree, formed basically from aulescent (xylemous) tissues.

Heightened caking qualities of low- and medium-metamorphosed coals of the Ulukhem and South-Yakutsky basins, as well as of the Novonietelkin deposit of the Irkutsk basin, are directly related to gel-potential tissues of paren-

chyma frequent in this area, and of the periderma of ginkgoaceous and coniferous plants. This, as well as other examples, proves very clearly the substantial influence of the initial nature of coal-forming plants upon the technological qualities of coal-forming plants upon the technological qualities of coal in their medium and especially in their low stage of metamorphism.

Additionally, the degree of primary oxidation and gel-formation of the vegetative mass has an important influence upon caking and coking qualities of coals. Coals containing a large quantity of unoxidized, gel-bearing substances, differ from others under otherwise equal circumstances in higher coking. Thus, "slightly reconstructed" coals of Donbas (that is: of low primary oxidation) containing, according to A. V. Usacheva [5], more light-gray gel mass than the "reconstructed" ones are characterized by their lower coking quality. Coals of the Anzhero-Sudzhensky region of Kuzbas contain many low- and medium-oxidized tissues with a small quantity of highly oxidized ones. These coals at VG [volatiles] = 14 to 16 percent give Y = 9 to 11 mm and solid coke. Coals of the Tom-Usinsky region of the Kuzbas of similar volatility have Y = 5 to 6 mm. According to their petrographic structure they differ from Anzher coal in higher content of highly oxidized and lower content of medium oxidized tissues. The latter apparently partially further coal caking.

The absorptive quality connected with presence of gas and the tendency of coal for self-combustion depend upon their content in micro-porous components of clear and unclear structures on one side and on gelified substances on the other [4].

Translated from O Klassifikatsii i nomenklature mikrokomponentov kamenykh uglei dlya tekhnologicheskikh tsel'ey: Sovetskaya Geologiya, no. 4, 1960, pp. 57-65.

The fractional division of organic coal micro-

components by degrees of primary oxidation and gelification is also necessary in connection with problems of phase analysis and the paragenetic associations of microcomponents of the inside of layers which characterize certain conditions of peat accumulation. Other similar micro-components are: unclear and hidden structure vitrains being formed under anaerobic conditions of a perennially wet swamp, desmite and attritus being formed under more aerobic conditions of the phase of "half-dry" peat bogs and running swamps. Coals of different phases differ in quality. Therefore, it is advisable to select them according to their microcomponent structure in polished section briquettes while making a quantitative analysis (table 1.).

For a clearer picture of the genesis and phase conditions of coal accumulation, it is also advisable to divide the mineral components into groups that are characteristic for one or the

other environment phase of a peaty section. This should be done together with the micro-count. For instance, syngenetic (authigenic) sulfides, sphaerosiderite, and montmorillonite are more characteristic of the stagnant swamp environment phase, and the small dispersion sand-clay material for running swamps.

A quantity count of "free" (mechanically not bound together) silica for the prognosis of a silica danger in coals is of great practical importance. It is difficult to distinguish silica from grains of feldspar in reflected light. Therefore, the definition of its content in polished sections is not precise and should be checked by studying control samples of coal in microsections, in transparent mounts with immersion, and with the help of microfirmness.

An additional check-up of coals in microsections is quite useful in order to define more

TABLE 1. Environment phase types of coals

Facies types of coals	Basic paragenetic associations (groups) of organic and mineral coal microcomponents	Character of distribution of mineral formations
Lustrous, massive, low in ashes	Vitrinites dl-2, cl-2 (basically vitrinites of hidden-unclear structure and structural ones; unoxidized and slightly primary oxidized xylovitrains); authigenic (syngenetic) sulfides, sphaerosiderite, montmorillonite and others ¹	Scattered and irregular dispersion
Lustrous, vaguely striped with lenses of argillite, ashy argillite	Vitrinites dl-2; cl-2 layer accumulation of fusainite a4-3, c4-3 and desmite with attritus; seams of clay and thinly scattered sand-clay material.	From irregular, roughly scattered (in layers) to thinly scattered
Half-lustrous streak-striped, low in ashes	Vitrinites dl-2; cl-2; xylinites bl-2; al-2; fusainites d3-4; c3-4; a3-4; desmite 1-2; xylo- and fusaino-attritus 2-4; siderite	Irregular
Half-lustrous streak-striped, ashy	Same plus numerous insertions of quartz and clay	Rather regular, more often thinly dispersed
Half-dull streak, low in ashes, granular	Desmite 2-1-3; xylo- and fusaino- attritus 2-4, fusainites d3-4; c3-4; xylinites b2-1; vitrinites d2-1, siderite	Irregular
Half-dull, massive ashy	Desmite 2-1; xylo- and fusaino- attritus 2-4; fusainites d3-4; c3-4; b3-4; xylinites b2-1; a2-1; vitrainite d2-1; clay and quartz	Regular, dispersive, scattered
Dull, massive, high in ashes	Same but with higher content of desmite, xylo- and fusaino- attritus and sand-clay formations	Regular, often dispersive, scattered
Dull-sooty, low in ashes	Vitrinite dl-2; cl-2; fusainite 4-3a; b4-3; authigenic sulfides and siderites.	Irregular

¹Summary of microcomponents given in diminishing numbers of sodium content.

correctly the origin of the vitrainized substance, which can be seen easier in a control light.

We consider as "free" silica those grains deriving from split coal and located in shellac cement of polished section briquettes; as "half-free," those grains deposited in coal, that may be released through stronger splitting; as "mechanically bound," we recognize grains deposited in clay sections among coals where they are released in very small quantities through splitting.

Considering practical needs and complex petrographic research, which encompasses not only the study of coking but also of other qualities, as well as the genesis of coal, we believe that the basis of a rational nomenclature and classification of microcomponents should be as follows: 1) the initial nature of coal-forming plants; 2) the degree of primary oxidation; 3) the degree of gelification; 4) paragenesis of

organic and inorganic microcomponents that characterize the environment phase of the peaty region; 5) composition and shape of deposits of mineral formations (the principle of isolating the microcomponents as such instead of their aggregates, like "mixtinite," should be especially stressed; 6) qualities which will change in connection with the quantitative relation of its containing desmite, thin attritus and mineral components. For this same reason the terms "collinite" and "telinite," as complex micro-component mixtures of different origin are called, degree of gelification and different conditions of formation are not appropriate. For instance collinite consists of homogeneous and nonhomogeneous vitrainized mass, desmite and real vitrain, Δ -vitrain, Δ -parenchite—all of which are different according to their nature and their conditions of transformation. Telinite consists of structural vitrain and xylen, a-xylenite and Δ -parenchite - all of which differ

and their microcomponents structure.

Medium content of ashes (A ^c , percent)	Average Total Content of Substance		K _f ²	Facies conditions and conditions of peat-accumulation
	Vitrainized	Fusainized		
4	84	12	0.14	Perennially wet, stagnant, little aerated swamps, or their sections which are remote from the shore line and from streams that were roaming on the peat-territory. Autochthonic conditions of accumulation.
10	82	9	0.15	Perennially wet, little aerated, stagnant swamps, periodically submerged. Suballochtono-autochthonic accumulation.
5	70	25	0.33	Swamps of transitory type (according to irrigation and aeration) with frequent oscillations of the oxidation-reconstruction limit, away from the shore line, of medium irrigation. Mainly autochthonous type of accumulation.
12	70	18	0.22	Swamps, mainly intermittent, comparatively well aerated closer connected with the shore zone of medium irrigation, autochthonous-suballochthonous accumulation.
6	47	48	0.53	Half-dry raised peat-bogs, well aerated. Autochthonous accumulation.
20	45	36	0.52	Flowing swamps or shore zones of peat-bogs, rather well aerated. Suballochthonous accumulation.
35	40	23	0.81	Flowing, strongly irrigated swamps, partly silted; comparatively poorly aerated (basically delta and fluvial sections of channels that were wandering within the territory of the peat-bog). Allochthonous conditions of accumulation.
6	52	43	0.19	Stagnant forest swamps. Autochthonous accumulation.

$$^2K_f \text{ (Fragmentary coefficient)} = \frac{\text{desmite} + \text{attritus}}{\Sigma \text{of other organic components}}$$

This coefficient characterizes to a certain extent the relative degree of biochemical processing of vegetation tissues.

according to the degree of gelification and coking [6].

In connection with the above statements we suggest dividing all organic coal microcomponents in reflected light for quantitative petrographic analysis into a number of groups according to botanical characteristics, degree of gelification (structure), primary oxidation and porosity (Table 2). Unlike existing classifications, we do not divide the microcomponents in two seemingly contrasting groups: "gelified" and "fusainized," because we believe that this is inexact, since gelified components can later become fusainized.

Organic microcomponents can be divided according to botanical characteristics into the following five basic groups: 1) woody; 2) parenchymic; 3) cortex tissues; 4) lipoids and 5) algae. The first three groups of tissues are named accordingly: 1) xylinites and xylovitrainites (xylene - woody substance); 2) parenchovitrainites and 3) subervitrainites. "Subervitrainites" are sections of more or less strongly gelified cortex tissues of plants [3]. In our classification "subervitrainite" is among the rock-forming components. In other classifications only "suberin" stands out as an element in a group of leptinite. In cases where the botanical nature of tissues cannot be defined owing to a high degree of metamorphism, because of gelification (with loss of traces of the cell formation), or for other reasons, tissues are given the group denomination of vitrainites. Tissues which went through a stage of strong oxidation (fusainization) also are gathered under one common group denomination of fusainites, inasmuch as botanic differences in such cases are without practical significance. In accordance with the structural and oxidation degree we add letters of the Latin alphabet to the group denominations (a, b, c, d) denoting structure, and arabic numbers (1, 2, 3, 4) denoting the degree of oxidation.

According to their structural indications (degrees of gelification) four groups of tissues stand out: 1) "a" structures: distinct structural tissues with free cell cavities, taking up over 50 percent of the vegetation fragment (mainly: xylenes and fusains according to their old denomination); 2) "b" structures: structural tissues with less than 50 percent of hollow cells (mainly xylovitrains and xylofusains); 3) "c" structures: unclear structural tissues of high gelification with small single openings of cell cavities or other traces of vegetation structure (structural vitrains), with a gradual transition to unstructural ones; 4) "d" structures: substance of hidden structure or without structure (structureless vitrains).

Gelified fragments with distinct structure of the cortex or wood, but unlike the "a" and "b" structure (without free cell cavities) are being

conditionally combined with tissues of unclear structure. According to their coking qualities they are closer to gelified tissues and therefore are combined with them; "a", "b" and "d" structures correspond to α -, β -, Δ structures (according to I. E. Valtz) [2]; "c" structure is to be considered as a combined one. The use of Latin letters instead of Greek is more convenient for printing.

Besides the above mentioned microcomponents, desmite, xylo- and fusaino-atritus stand out especially. The term "desmite" has been adopted from I. I. Ammosov [1], but unlike him we consider as desmite only small ($<10\mu$) sections of the basic structureless colloid mass, which is more or less evenly impregnated with form elements and has in most cases been touched by processes of primary oxidation. Being formed under more aerobic conditions compared with structural vitrains and those of hidden structures, desmite has a different coking quality, microfiness, tendency for oxidation and a number of other characteristics.² Genetic and quality characteristics of desmite points it out in the vitrain group as an independent microcomponent.

The terms "xylo-atritus" and "fusaino-atritus" denote small ($<10\mu$) vegetation fragments of lignin cellulose tissues of different degrees of gelification and primary oxidation. Atritus, which we isolated, is close to mixinites according to its substance and dimension of its form elements, but unlike the latter has no non-transparent basic mass. Xylo- and fusaino-atritus are paragenetically connected with desmite. They all are characteristic for coals of environment phases of "half-dry" peat-bogs and running swamps. Their isolation in the petrographic quantity analysis is especially recommended.

The isolation of desmite, xylo- and fusaino-atritus as independent microcomponents eliminates mixinites from the nomenclature of microcomponents. Mixinite is a thin mixture of desmite, atritus and mineral constituents [6].

According to primary oxidation all organic microcomponents are divided into unoxidized, slightly-, medium-, and highly-oxidized ones and are marked with the figures 1, 2, 3, 4, according to the first, second, third, and fourth stage of primary oxidation.

According to the degree of porosity five groups of components stand out: nonporous, slightly porous, porous, strongly porous, and heteroporous.

²It is to be assumed that desmite is connected with the greatest content of some rare elements in coals.--A.B.T.

TABLE 2. Nomenclature of coal microcomponents (studied in reflected light)

Groups of Components				Degree of Primary Tissue Oxidation			
Gelification degree	Porosity Degree	Structure	Initial Nature	1-unoxidized gray (red) ¹	2-little oxidized light gray (brown-red)	3-medium oxidized grayish-white (brown)	4-strongly oxidized yellowish-white (black)
Ungelified	Strongly porous	Pronounced structural	Basically woody	xylinite a 1	xylinite a 2	fusainite a 3	fusainite a 4
Partly Gelified	Porous	Structural	Basically woody	xylinite b 1	xylinite b 2	fusainite b 3	fusainite b 4
GELIFIED	Of low porosity and partly non-porous	Vaguely structural and partly structural ²	Woody parenchymic cortical	Vitrinite c 1 xylovitrinite 1 parencho-vitrinite 1 subervitrinite 1 ³	Vitrinite c 2 xylovitrinite 2 parencho-vitrinite 2 subervitrinite 2	fusainite c 3	fusainite c 4
	Unporous	Non-structural and of hidden structure	Products of colloid regeneration of various vegetal tissues	Vitrinite d 1	Vitrinite d 2	fusainite d 3	fusainite d 4
		Non-structural basic body of rock, dispersion fissures		desmite 1	desmite 2	desmite 3	-
	Heterogelified	Non-porous and heteroporous	Structural and non-structural	Small fragments - mostly of woody tissues	-	Xylo-atritus 2	Fusaino-atritus 3
Lipoids	Non-porous	Form elements	Spores, pollen, cuticle	Leiptinite 1	Leiptinite 2	-	-
Algae			Algae	Alginite 1	Alginite 2	-	-
Mineral Formations		Clay and clay minerals	Silica: a) free, b) half free, c) fixed				
			Sulfide: a) syngenetic, b) epigenetic				
			Carbonates: a) syngenetic, b) epigenetic				

¹ In parenthesis the color of tissues in drifting light is shown. Lipoids and algae are roughly divided into two groups according to oxidation degree: of more or less dark color.

² By "structural" tissues we mean in this case gelified vegetative fragments or their parts with well-defined structure of the core and xylem, but with hollows of the cells filled with amorphous-organic substance. Such tissues appear to be non-porous and are not often to be found in reflecting light.

³ A. A. Larishchev (3) denotes this kind of core by the name "vitraino-suberin".

This way the suggested classification of organic microcomponents according to their origin, degree of gelification, primary oxidation and porosity makes it possible to study a number of most important qualities of coals, like their coking, presence of gas, tendency for self-combustion, etc.

For this classification we took into consideration a number of valuable suggestions and remarks made by: V. P. Shorin, E. M. Senderson, I. N. Zvonarev, I. E. Valtz, A. A. Larishchev, I. V. Eremin, N. M. Krylov and others. The author wants to express his deep gratitude to all these comrades.

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THE GAS GEYSER OF WESTERN TURKMENIA AND THE MECHANISM OF ITS ACTIVITY¹

by

M.I. Subbota

ABSTRACT

A gas and water geyser in Turkmenia, formed when an exploratory well for petroleum intersected a fault fissure, is described. Accumulating gas, rather than superheated water, creates the necessary pressure to start geyser activity. No siphoning process is needed to explain geyser action.-- M. Russell.

* * *

Geysers are a particular form of rarely encountered hot spring occurring in volcanic regions. Within the Soviet Union they are well known only in Kamchatka [1, 2, 3, 4]. Still rarer are gas geysers, which, however, have many features in common with the normal type.

In February 1958 we became acquainted with a new gas geyser in Western Turkmenia. The Turkmenian geyser has a very simple structure: it is formed at the site of an unsuccessful bore hole.

The history of this geyser in general outline is as follows: In 1953 the petroleum organizations of Turkmenia drilled some exploratory wells. A topographic high corresponding to the anticlinal fold of the Boya-Dag is located approximately 60 kilometers southwest of Nebit Dag mountain and is surrounded by salt bottoms and takyr. It is not very high, about 120 meters over the level of the surrounding salt bottoms, and is elongated east-west. Sandy-clayey, strongly calcareous deposits of the Apsheronian and Akchagylian stages compose its rocks. In the western portion it is complicated by the Kara-Burun obelisk which has the form of a steep pillar. The Kara-Burun is formed of red sandstones and pierces the rather gently sloping Apsheronian deposits. It is thought that this mass is the relict chimney of an ancient mud volcano. East of the Kara-Burun obelisk is a saddle with which much oil, gas, and hot springs are associated. Solidified petroleum encrustations have been formed around the oil discharges, and, at the hot springs, are red and yellow deposits of iron oxide, and white encrustations of salt. All of the sources of oil and hot water are associated with faults, which are quite numerous on the anticlinal fold of the Boya-Dag.

The well was drilled in the upper part of the saddle, 400 meters east of the Kara-Burun obelisk. In the process of drilling, the hole cut through into a fault fissure at a depth of

somewhat more than 300 meters. Salty hot water (60°C), accompanied by a weak gaseous expulsion, spouted from this fissure. The yield of water was so great as to prevent further drilling. The equipment was removed and the hole was abandoned without capping.

After some time the hole became a periodic gusher: in other words, a geyser. At first it erupted every 3.5 to 4.5 hours, later at intervals of 11 to 12 hours. In 1957, the geologist M. I. Korabelnikova observed the period to be 29 hours. We were able to visit the Boya-Dag on February 26, 1958, when the eruption period was 33 hours, 17 minutes. The period was not constant, but varied between 29 and 33 hours.

In its visible portion the geyser possessed the following structure. The vertical canal of the geyser, extending to a depth of about 100 meters, cut through an almost unvaried section of Apsheronian sandstones. Its mouth was located on very dense sandstones of the same age which were polished by the water and had a smooth surface. The geyser opening or vent, as compared with the original bore hole, had broadened, and its cross-section was of irregular circular form. At the mouth the canal measured 40 x 44 cm. At a depth of 100 meters, the hole was intersected by a gaping fault fissure filled with water and rock detritus. At the start of our observations, a wide and very gentle crater, of 5 meters diameter and 20 to 50 centimeters in depth, had formed on the surface around the opening canal. On one side the crater was washed clean; on the slope of the mountain was a sinuous channel by which the water flowed off.

The Turkmenian gas geyser was observed to go through the following stages of action.

1) Gentle discharge of gasified water from the mouth into the crater, which discharged it by channel onto the surrounding salt flat. Much bubbling from escaping gas was observed at the crater's center. This stage of the geyser's activity was the most prolonged, and continued for approximately 25 to 29 hours.

2) Increase in flow: During this period the yield of water and gas increased, water began to well up 30 to 50 cm above its level in the crater and

¹Translated from *Gazoyye geyzer v zapadnot turkmenii i mekhanizm yego deystviya*: Sovetskaya Geologiya, 1960, no. 4, p. 120-123.

to "boil" with the large amount of discharged gas. Duration of this stage was 4 hours 12 minutes and continued up to the time of gushing.

3) Gushing. This usually begins abruptly. The water in the opening suddenly rises quietly to 1 meter above the crater level, then, in a second, it rises to 2 meters above the crater level, then within a few seconds more, becomes a fountain reaching 30 to 40 meters in height. The diameter of the column of water is about 0.4 meters at the base and, in the upper portions, it widens to 2 or 3 meters. The water gushes in streams of tremendous force, with rumbling and noise. The greatest height measured on February 26 was 38.7 meters. On a cold winter day, the fountain gives off clouds of steam producing an impression of boiling. In point of fact the temperature of the water does not exceed 62°C (observed 1958). The fountain falls back into the crater and flows off along the channel. Very little returns to the geyser throat. The total gushing period is about 11 minutes, during 9 of which the geyser is operating at full power. At the end of the gushing period, the height of the column falls off, the geyser begins to pulsate, throwing off water in spurts, and finally becomes quiescent.

4) In the final stage, the remains of the eruption water from the drain ditch flow back into the throat which at this moment is becoming dry. The sound of echoes and rumbling can be heard at a depth, with escaping gas. But gradually the throat begins again to fill with water, the discharge of gas falls off, and, after 1 or 2 hours, water has risen to the mouth and begins to flow quietly again.

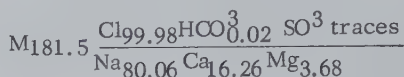
Gas is the motive power of the fountain. In order for the spring to gush, an accumulation of gas must first take place. No such accumulation of gas was observed around the hole when drilling was completed. It appeared only after several years, in conjunction with a power stream of hot water which penetrated the bottom of the throat from the fissure, enlarged the cavity of the fissure and brought the products of this disintegration to the surface.

Evidently the cavities first formed within the fissure were small, and the accumulation of gas within them slight, though entirely sufficient to overcome the pressure of the column of water in the hole and to expel it to the outside. For that reason the period between eruptions was small.

Gradually the cavities were enlarged, the accumulation of gas became greater, and the periods between eruptions increased, together with an increase in the strength of the eruption. As indication of the fact that gas has accumulated at the bottom of the canal, heavy metal objects accidentally dropped into the geyser are ejected at the time of gushing. The accumu-

of gas in the cavities of the fissure continues until its pressure equals that from the weight of the column of water in the vent.

The water of the geyser, according to our analyses, consists of brine with a mineralization of 181.5 grams per liter, and is of chlorine-calcium type. Its composition may be represented by the formula of Kurlov, thus:



It is possible, therefore, to assume that, at the moment of gushing, the gas pressure must exceed 10 atm.

Very little gas escapes with gushing. This is proved by the fact that a water-gas fountain burns with an enormous flame among streams of water without the flame being extinguished, according to our investigations the gas contains 83.1 percent of methane and heavy hydrocarbons, 16.5 percent of nitrogen, and 0.4 percent of carbonic acid gas.

Our observations at the Turkmenian geyser indicated that the following conditions were necessary for its formation:

1) The presence of comparatively hard rocks (sandstones) at the mouth, throughout the vent of the geyser, and at the bottom, where these rocks are cut by the fissure;

2) The absence within the profile of soft clayey-rocks, which if present would mix with the water of the vent, forming a clayey mass which could stop the free escape of water and gas;

3) The presence of fault fissures and a zone of fractures;

4) A sufficient quantity of water entering the cavities under pressure;

5) The presence of gas, separating out of the water, or appearing independently.

The separated gas accumulates within the fractured zone up to the moment when its pressure exceeds that of the water in the geyser vent.

The periodic ejection of gas and water from a gas geyser can be likened to certain ordinary gasified springs. In such springs fine bubbles of gas are not able to penetrate instantly to the surface. Their pressure accumulates in bends of the canal until it exceeds the counterpressure of the water. An agitated separation of the gas is produced, followed by another intermission. The author has repeatedly observed such springs

in various parts of the Soviet Union. It therefore appears that no special siphoning mechanism is required for the operation of a gas geyser.

The Kamchatka geysers, structurally and in character of eruption, are almost identical with the Turkmenian gas geyser. The only difference is that they erupt with steam, while the Turkmenian geyser erupts with gas.

However, it is undoubtedly true that gas plays some sort of role in the activity of the Kamchatka geysers particularly in the initial stages of eruption. Gas accumulating deep within the supply canal, and then rising, diminishes the pressure of the water in the canal. This leads to boiling at a temperature considerably below the boiling-point. Measurements indicate that the temperature of water in various geysers varies from 60° to 98°, and at the moment of eruption reaches 99°, which is to the boiling point at the particular altitude above sea-level.

Among the Kamchatka geysers are some whose eruptions are repeated every 13 minutes, and even oftener. These geysers are large, reaching a height of 20 meters and continuing for 3 minutes. One assumes that during the 13 minutes following eruption the water in the supply canal cannot be heated to temperatures greatly exceeding 100°. Springs with strongly heated water are in general rarely found. One such spring is known in Yellowstone Park [1, p. 101]; this spring emits steam continuously, although it has no geyser action.

Thus the important role of gases in the processes of eruptions of the normal geyser becomes understandable, in view of the fact that no superheated geyser waters are known.

In the valley of the geysers is a spring which emits a fountain of water continuously, with steam [1, p. 66]. The temperature of the water of this spring is not different from that of the geysers. Evidently the continuous fountain is produced as the result of the continuous appearance of gas within the water. Here the water boils not at the depth of the canal, but near the surface. It is entirely probable that at the supply depth, vent conditions do not permit accumulation of gas. It is possible that this is prevented by the strong pressure of the supply water. This spring is comparable to the Turkmenian geyser at its initial moment of activity, when no cavities had yet been formed within its depths where much gas accumulation could take place.

After a periodic eruption the boiling within

the geyser is cut short, since all the heated water has been ejected from the canal, and all the returning water is a temperature below the boiling point.

We do not reject the possibility that, in some instances, the cessation of boiling is due to the inflow of cooled water from side branches of the canal, but this situation is definitely not necessary for geyser action. It might be true in the event that, during eruption, no gas took part in the operation; in such a case the water would have to be heated to 125° and more, as is suggested by T. I. Ustinov [1, p. 100]. But since eruption can be initiated by the means of gases in the presence of moderate heating, it appears that cessation of boiling requires only a very small amount of slightly cooled water within the geyser itself.

In 1950 Vart brought out a hypothesis on the participation of gases in the Icelandic geysers. Later, in 1954, the same position was adopted by S. I. Naboko regarding the Kamchatka geysers. Both investigators believed that gas appeared at a depth lower than the pressure of the water column and created the prerequisites for the formation of steam [4, p. 174 and 179].

Study of the Turkmenian gas geyser has shown that between normal geysers and gas geysers there is very much in common in general properties, particularly in the structure of the eruptive mechanism. The theory of "siphons" is completely antiquated.

In conclusion we wish to express the hope that the Boya-Dag with its unique geyser will be made into a reserve.

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METALLOMETRIC SURVEYING IN MOUNTAINOUS AREAS BASED ON ALLUVIAL DEPOSITS¹

by

A.P. Solovov and N.Ya. Kunin²

REVIEWER'S NOTE

Very good paper on geochemical prospecting of stream alluvium deposits. Find essentially no difference in metal content of sizes less than 0.25 mm, 0.25 to 0.5 mm, 0.5 to 1 mm and 1 to 3 mm. Authors derive formulas for tonnage of metals producing anomalies. Geochemical studies as case histories are shown in two large mountainous areas where stream deposits are checked every 500 m for a regional study. The alluvial deposits are 2 to 3 km long and show up well in steeper gradient streams. The alluvial testing is much better and cheaper than more detailed prospecting for dispersion halos on a grid.

ABSTRACT

A most economical prospecting method in mountainous areas is a metallometric survey along stream alluvial deposits by means of spectral analysis of alluvial-proluvial samples. Judging from a conspicuous predominance of mechanical dispersion forms for most previous metals the authors suggest a method of quantitative estimation of the "expected" reserves, concentrated in the basin of the stream intake and measured from the results of metallometric survey. The conclusions are based upon data gathered during the three year prospecting and exploration works for lead in a high-mountainous region of West Tien-Shan. --Auth. English summ.

It is undisputably clear now that the search for ore deposits in folded and mountainous areas should include metallometric surveying. However, questions pertaining to methods and techniques of metallometry should be fully discussed.

Of all the prospecting methods applied in the U. S. S. R., the most efficient are areal metallometric surveys on a scale of 1:50,000, involving the search for dispersion halos of ore deposits. This method calls for sampling of contemporary eluvial-deluvial deposits along a rectilinear grid system.

Reconnaissance and small-scale metallometric surveys are still applied on too limited a scale. They should serve primarily for the general evaluation of an area under investigation and for the information on its metallogeny. In mountainous areas with an intricate drainage pattern, the most efficient method for such surveys is to search for alluvial deposits from contemporary runoff transporting solid particles. Alluvial deposits of ore occurrences in piedmont alluvial deposits of dry channels, creeks, and small rivers attain lengths of several kilo-

meters and are sure to be revealed by a metallometric methods using distances of 250 to 500 m between sampling points, while the search for dispersion halos is based on distances of 50 to 100 m. Current instruction of metallometry [2] prescribes a scale of 1:200,000, so that the number of points sampled in one square kilometer in the search for alluvial deposits equals one fifth that prescribed for dispersion halo searches at the same scale. In addition to a reduction in expense, metallometric prospecting for alluvial deposits secures a more objective evaluation of the territory under investigation with respect to its ore-bearing potential, while the results of small-scale areal surveys based on dispersion halos have a somewhat random character.

The advantages of prospecting for alluvial deposits are clearly exhibited in inaccessible mountainous terrain and especially in alpine regions. There is no doubt that mining in these regions, which necessitates great investment may be worthwhile only where possibilities of large and very large ore deposits are discovered. A characteristic feature of surveys based on alluvial deposits is that they reveal only large ore occurrences, and inevitably miss most small occurrences which may be discovered at later stages of exploration in new areas.

¹ Translated from *Metallometricheskaya s'yemka po potokam rasseyaniya v gorn'nykh rayonakh*; *Sovetskaya geologiya*, no. 5, 1960, pp. 32-46.

² Kazakh Geophysical Trust of the Ministry of Geology and Conservation of Natural Resources, Kazakh S.S.R.

The appearance of alluvial deposits of ore is associated with the erosive and dissolving action of atmospheric precipitation and with the intermittent and perennial streams of meteoric origin. In mountainous regions, thanks to the active processes of denudation, the solid phase

ase plays a predominant role in the alluvial deposition of ores. Records of many years' investigations indicate that soluble salts removed in the basin of the alpine Vakhsh River, a tributary of the Amu-Darya, make up less than 3 percent of the total solid and soluble runoff [5]. Taking into account that the coefficients of water migration of all colored and rare metals, with the exception of zinc, are less than one, it is permissible to consider the alluvial formation of ore deposits in mountainous areas as a process of purely mechanical dispersion [6].

The formation of ore in the alluvial-piedmont deposits in a stream bed occurs on account of the erosion of dispersion halos located in a given drainage basin.

This determines the direct proportionality between the productivity of halos of dispersion P and the productivity of a given dispersion flow P' which may be described by the expression:

$$P = k'P', \quad (1)$$

where k' is coefficient of proportionality.

It will be shown later that formula (1) satisfies to a degree conditions corresponding to the flows of the first order, having no side tributaries and having limited drainage basins.³

The productivity of an alluvial deposit at a given point P'_x is, in turn, determined by the area of the drainage basin S_x and by the local excess in metal content in alluvium over the background content, i.e.,

$$P_x = S_x (C'_x - C'_0), \quad (2)$$

where C'_x is the observed and C'_0 the background content of a given metal.

The value P'_x , expressed in percent of square meters, gradually increases in the zone directly influenced by the ore body. Beyond this zone, it remains constant or decreases depending on local conditions [6].

In mountainous regions, a direct ratio is clearly observed between the productivity of alluvium and the order of magnitude of the corresponding ore occurrence in bedrock. On the one hand, this ratio is attributed to the continuous renovation of halos due to erosion, and to the highly dissected relief inducing the simultaneous formation of dispersion halos at various altitudes. Consequently, a ratio should be also observed between the productivity of the dispersion flow and the order of magnitude of ore occurrence in bedrock in the erosion basin.

Extending to a certain depth the values of productivity of a dispersion halo, computed from formulas (1) and (2), and taking into account the unit weight of rocks (2.6 gr/cm^3), it is possible to determine the magnitude of metal reserves in a given erosion basin from the following formula:

$$Q = P' m^2 \% \cdot k' \cdot 2.6 \cdot 1 \text{ m} \cdot 10^{-2} \quad (3)$$

where Q denotes metal reserves in tons to a depth of 1 m.

If there are data available for an approximation of the value of coefficient k' , then results of a metallometric survey based on dispersion flows may be utilized for a quantitative evaluation of the ore-bearing possibilities of the territories under investigation.⁴

The authors studied two adjacent areas in a high-mountainous region of Central Asia.

The first included the greatest part of the Ugam Range and the northern part of the Karzhantau Range. The second covered the western part of the Talass Alatau Range (Maydantal and Oygaing Rivers). The region is characterized highly dissected mountainous terrain. The first area has peaks ranging from 1,800 to 3,500 m, the relief being 1,000 to 1,500 m. Peaks of the latter area are from 3,000 to 4,500 m; the river bed about 1,400 m.

The rivers are typically mountainous with steep gradients and rocky beds. They are fed from snow melting in summer and from occasional showers. The annual precipitation ranges from 600 to 1,200 mm. The rivers transport a great deal of solid material which is then deposited outside the region under consideration.

A detailed geologic survey had been made here, as well as repeated explorations with schlich testing.

No ore occurrences having been discovered, the Ugam-Karzhantau area had been judged unfavorable for ore deposits.

Schlich testing of samples from the Oygaing River basin had revealed the universal distribution of W, Cu, Mo, Pb, and Sn minerals. This factor prevented the evaluation of individual sections in this basin.

Between 1956 to 1958, two areas were investigated by means of the metallometric survey of alluvial deposits: an area of some

⁴The calculation of reserves is limited to a depth of 1 m, because during the survey the mode of the ore occurrence is not yet clear. Later on the calculation may be easily performed to other depths.

³By merging, the flows of the first order form the flows of the second order; etc.

3,000 km² was covered by the survey at a scale of 1:2,000,000, and a territory of 150 km² by the survey at a scale of 1:50,000. The following work was simultaneously performed on these areas: 1) areal metallometric surveys of dispersion halos were carried out at a scale of 1:50,000 on arbitrarily selected areas totalling 200 km²; 2) the same at the scale of 1:10,000 in an area of 90 km²; 3) electric and magnetometer surveys; 4) more than 60 trenches and pits were dug out.

During metallometric surveying of alluvial deposits at a scale of 1:200,000, samples were taken along routes following stream beds. The distance between the routes averaged 2,000 m; that between the sampling points, 500 m.

To forestall the chore of a more detailed survey, intermediate samples also were taken at intervals of 250 m along the same routes. Initially, only the samples of the basic grid system were studied. Where anomalous metal concentrations were found in these samples, the intermediate samples were also analyzed. Thus, the most promising intervals along the routes were studied in the field without revisiting the locality.

In each point, 100 gm samples were taken from both the sandy and the silty-clayey fractions of alluvial-piedmont deposits. They were taken several centimeters down in the dry or shallow-water portion of the stream bed. The points of sampling were plotted by eye on the 1:100,000 map or on the contact prints of air photographs at a scale of 1:30,000 and recorded in a notebook.

The samples were subjected to semiquantitative spectrographic analysis for content of Hg, Pb, Zn, Sn, Bi, Ag, Mo, W, Be, Co, V, Ba, Cu, and others to total of 26 elements; magnetic susceptibility was determined. Samples taken from the silty-clayey fraction were subjected to β -measurements and to pearl luminiscent analysis.

During the metallometric surveying based on dispersion flows at a scale of 1:50,000, the distance between points of sampling was 100 m. Special attention was devoted to the investigation of all dry and shallow stream beds of the first order.

In order to determine relative amounts of particular metals in silty-clayey and sandy fractions of alluvium, as well as in classes with certain grain sizes, about 5,000 samples were subdivided before analysis into four size grades: less than 0.25 mm; 0.25 to 0.5 mm; 0.5 to 1 mm; 1 to 3 mm.

Without analyzing the results in detail, let us merely note that an adequate agreement of lead, zinc, and vanadium content in both sandy

and silty-clayey fractions and in all grain-size classes was established, although these elements differ in their behavior in the supergene zone. This indicates that equal results are obtained from the analyses of metallometric samples taken from any fine-grained fractions of alluvium. Therefore, when selecting a sampling point, one need not allow for stream velocity, width or bends, as is done for schlich surveying. It is hard to draw a similar conclusion for other metals because they were not enough points of anomalous content. After results were studied, the size grade 0.25 to 0.5 mm was taken as standard for the silty-clayey fraction.

The survey gave most important data for lead, along with background and anomalous concentrations of zinc, copper, mercury, tin, molybdenum, tungsten, bismuth and vanadium.

A lead concentration of 5×10^{-3} percent was taken as the minimum lead content in an alluvial deposit. The maximum length of deposit was 4 km, with the lead content running from 20×10^{-3} percent to 300×10^{-3} percent. The length of deposits with a high lead content is always at least 1 km.

There are vast areas within the investigated territory where the lead content in alluvium does not reach anomalous concentrations. However, several zones were found with high lead concentrations. The most important are the Badamsay, Kulanchak, and Oygaing districts.

Most detailed studies were performed at Badamsay. Here, the areal metallometric survey at a scale of 1:10,000 and data from exploratory pits provided information for a comparison of alluvial deposits with dispersion halos and bedrock ore occurrences. Along creek 13 an alluvial lead deposit was traced from the creek mouth to its source, a distance of 1,400 m. Lead-rich dispersion halos in this drainage basin had a maximum lead content of 1 percent.

Taking typical points of the deposit, we computed values of its productivity P' from formula (2), as well as values of productivity of halos corresponding to these points:

$$P = \Delta \cdot l (\Sigma C_x - C_0 \cdot N), \quad (4)$$

where $\Delta_x = 20$ m is the distance between points of observations;

$l = 100$ m is the distance between profiles of the metallometric survey at the scale of 1:10,000;

ΣC_x is the sum of anomalous values in the dispersion field;

N is the number of points included in the computations.

From the values of ratios between the product of the dispersion value and the productivity of flow, the coefficients of proportionality

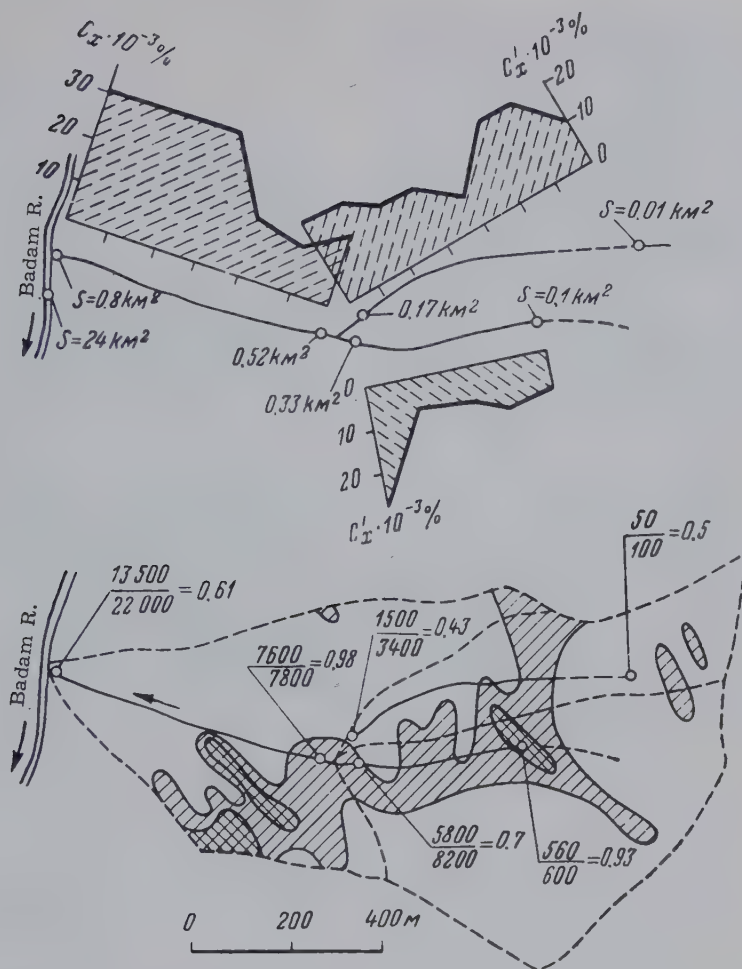


FIGURE 1. The lead content in dispersion halos and alluvial deposits along creek 13

k' were estimated. It is apparent from Figure 1 that these values range from 0.43 to 0.98.

The dispersion flow along creek 10 has a length up to 1,500 m. The maximum lead content in dispersion halos here reaches 1.5 percent. The occurrence of rich oxidized lead ores in bedrock was confirmed by trenches. Graph of percent of $P'_x m^2$ (figure 2) shows a continuous increase in the productivity of the

flow from its source towards the mouth, attesting to the fact that the creek receives ore particles throughout its course. This is also confirmed by the distribution of the dispersion halos in the creek basin.

In order to avoid the random errors, mean values of P'_x were additionally computed, as an average from three adjacent values. From an intersection these values describe the

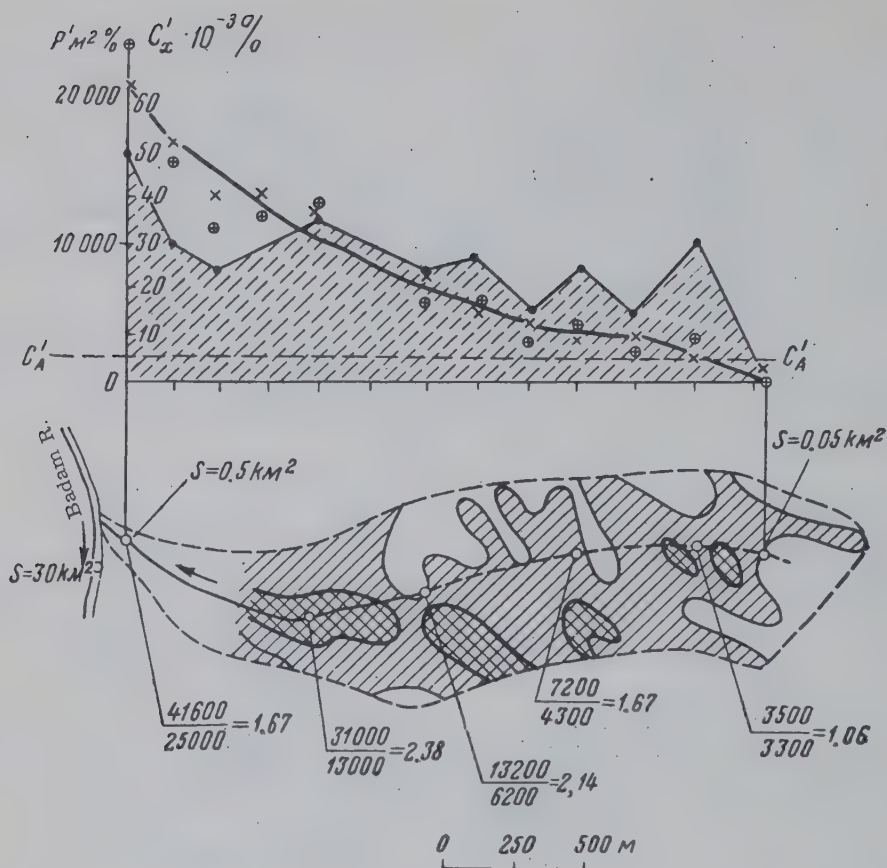










FIGURE 2. Lead content in dispersion halos and alluvium along creek 10

-  - points of sampling of the dispersion flows
-  - graph showing lead content
-  - area of the erosion basin
-  - area of the halo with a lead content ≥ 0.02 percent
-  - area of the halo with a lead content ≥ 0.1 percent
-  - $\frac{P}{P_1}$ ratios (values in percent of m^2)
-  - computed values of P'_x
-  - graph of mean values of P'_x

increase in P'_x as a smooth curve.

For this creek, the values of coefficient k' range from 1.06 to 2.38.

Analogous comparisons of productivity of dispersion halos and alluvial deposits were performed for the whole area covered by detailed metallometric surveying, exploratory pits and trenches. Values of k' computed for 81 cases are presented as a frequency curve (figure 3). The curve is smooth and symmetrical; it clearly shows that $k' = 0.9$ is the most abundant value. Up to 85 percent of all values of k' lie in the interval from 0.3 to 3.0. Therefore, $k' = 1$ in this case. As a rule, this value of k' will not differ more than three times from its true value.

Variations in the value of coefficient k' depend on several geologic factors. Variation of thickness of the average graded layer throughout the basin is of the greatest significance, also gravitational differentiation of minerals in stream beds.

Where a dispersion halo was located at the source of a small creek of the first order and where $S = 0.64 \text{ km}^2$, we obtained a graph of

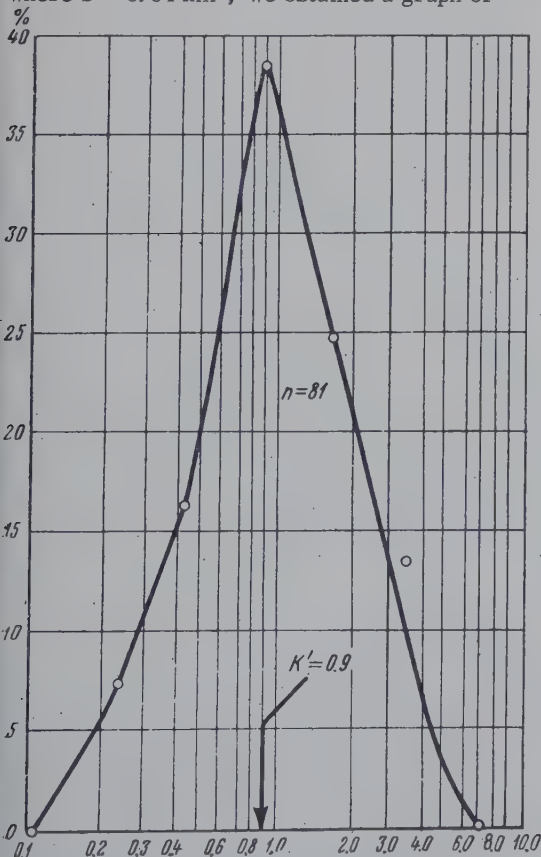


FIGURE 3. Frequency curve for values $k' = \frac{P}{P_0}$, for lead

productivity of the alluvial deposit which fully agreed with the theoretically established relationship (figure 4, creek 9); in the interval between points 75 to 65, the productivity of the alluvium continuously increases. This interval corresponds to the section supplied by material from the zone of the dispersion halo. From point 65 to the creek mouth, the productivity of the alluvium remains practically constant, thus attesting to the absence of a metal supply. More complicated conditions are found along the left tributary of creek A. Here, in addition to the introduction of metal in the headwaters, a second increase in productivity of the flow is observed, evidently from another source. Reasons for a decrease in productivity of the medium part of the flow (points 61, 59, and 57) will be considered later.

Figure 5 presents a map of the ore-bearing potential of the Badam Creek district. For compilation of this map, the results of the metallometric survey of alluvial deposits were used. The computations were performed according to formula (3), with $k' = 1$. The computed quantities of metal Q' should be certainly considered to be tentative, characterizing only the possible order of magnitude of lead "reserves." Therefore the magnitude Q' we express in decimal numbers = $n \cdot 10$, $n \cdot 10^2$, $n \cdot 10^3$, etc., where n may range from 1 to 9.

The results distinctly indicate the contour of the Badam Creek ore field which is undoubtedly larger than the area covered by the detailed surveying. Considering that on the average, $n = 3$, it is possible to estimate the total prospective lead "reserves" of the Badam Creek ore field to a depth of 1 m as equal to $n \cdot 10^3$. This figure, of course, may include metal reserves of no economic importance located in the zone of mineralization. Present metallometric methods cannot assess such areas. It is clear that prospecting work should be continued in the Badam Creek district. The results to date from exploration trenches and pits do not contradict the above computations.

The results of surveying the Kulanchak field are very important. Lead alluvial deposits of considerable length and high metal content (C'_x up to $100 \cdot 10^{-3}$ percent Pb) were discovered here. These deposits indicated a vast new ore zone missed by previous geologic surveys and explorations. Let us mention in passing that the lead alluvia were first discovered here in 1957 in the course of metallometric surveying at a scale of 1:200,000. In 1958, surveys of alluvial deposits at a scale of 1:50,000, were made within the area where ore possibilities were discovered. This survey fully confirmed the previous year's findings and secured data for evaluation of the possibilities of this area. A specific feature of the lead deposits here is that the bulk of ore material is introduced into the stream bed where a stream

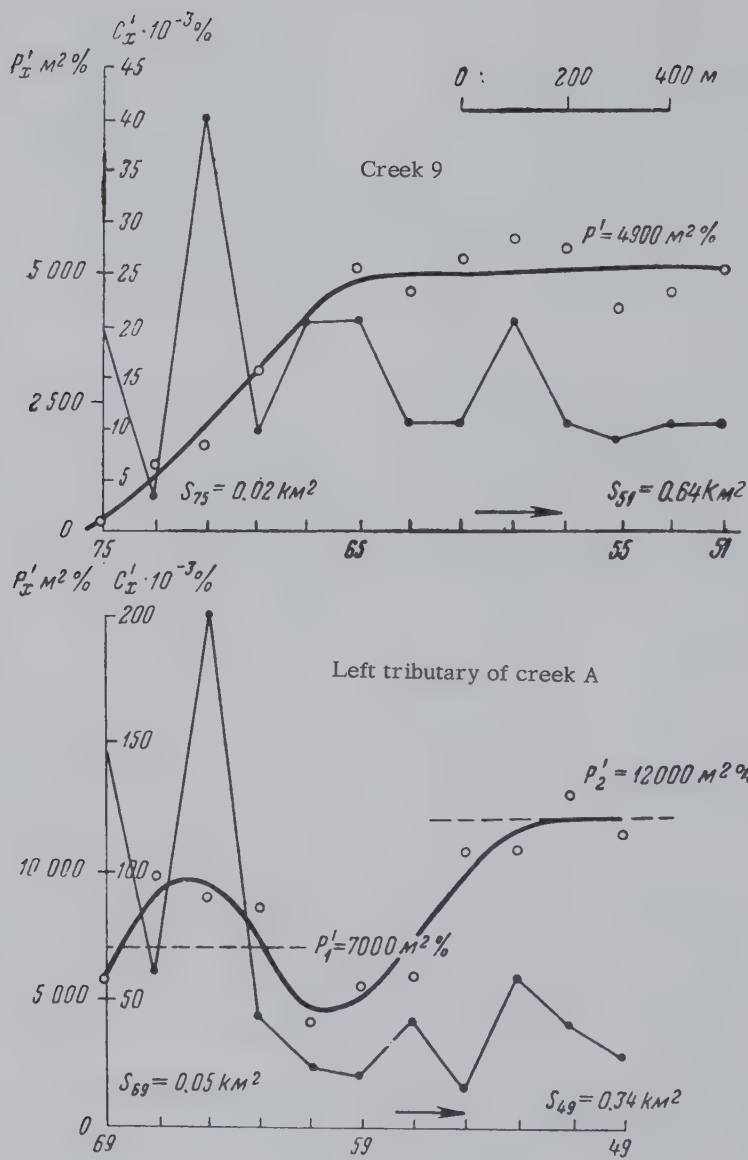


FIGURE 4. Graphs of the lead content and the productivity of alluvial deposits



FIGURE 5. Sketch map showing results of the metallometric survey of the Badam Creek field

- routes along the alluvial deposits
- lead content from 5 to $10 \cdot 10^{-3}$ percent
- lead content from 10 to $30 \cdot 10^{-3}$ percent
- lead content $> 30 \cdot 10^{-3}$ percent
- lead reserves in the erosion basin to a depth of 1 m on the order of $n \cdot 10$ tons
- the same, on the order of $n \cdot 10^2$ tons
- lead reserves in the tributary basin taken into account in computing the reserves along the main stream
- data confirmed by the dispersion halos
- area covered by the survey at a scale $1:10,000$
- alluvial deposits of the Ugam River
- Cretaceous deposits
- Lower Carboniferous limestones
- Upper Variscan granitoids

as a drainage basin of considerable area, compared to creek length, and the gradient is close to the equilibrium profile. Erosion basins of such creeks differ morphologically from creeks 9 to 13 of the Badam Creek field discussed above.

Computations of productivity of the alluvial deposit along creek V and Kulanchak Creek, performed on the basis of the conventional formula (2) showed that a continuous increase

in the value P'_x is followed by a distinct and sharp decrease in this value. This contradicts the condition $P'_x = \text{const.}$ for the area located below the zone influenced by the ore body, and raises doubts regarding the estimate of productivity within the zone of a steady increase in productivity.

To explain this deviation from the hypothetical it should be kept in mind that the norm for an alluvial deposit is considered to be a

process of continuous transportation of eroded material beyond the limits of the basin under investigation. This condition is generally satisfied in mountainous regions, because most solid material transported by water is deposited outside the mountainous region. For short stream beds of the first order having a steep irregular longitudinal profile, this condition is fully satisfied. For example, described above creek 9 (figure 4) has a steady gradient and a total drop equal to 500 m for a length of 1,200 m.

In large creeks of the first and higher orders, where the gradient decreases noticeably from its source to the mouth, most solid material is transported during the brief high water period, when the mountain rivers of Kazakhstan and Central Asia remove 70 to 90 percent of their erosion products [5]. During low water, the stream bed itself serves partially as an erosion dump. As a result, the alluvial deposits of the stream bed are no longer typical of the whole drainage basin at a given point, but rather the erosion products of adjacent slopes are in greater proportion. This certainly leads to a sharp increase in P'_x values in the zone where the ore material is introduced. This increase is due both to a higher value of C'_x (as compared with the average sample) and to exaggerated dimensions of the overall drainage basin S_x (as compared with the area of the basin adjacent to a given point along the stream) which were expressed in formula (2). Below the influence zone of the ore body, the increased productivity of the alluvial deposit obviously will decline at some point, due to the fact that the composition of such deposits is affected chiefly by nonmetalliferous surface materials on adjacent slopes.

In order to eliminate distortion, an empirical formula may be used to determine the "effective" area which should be taken into account in alluvial-deposit-production estimates:

$$S_{ef} = S_x - \eta_x S_0 + \epsilon_x (S_x - S_R) \quad (5)$$

Here S_0 designates dimensions of the non-metalliferous area lying above the ore body;

S_R denotes the total drainage basin area down to lower limit of the zone of influence of the ore body;

correction factor $\epsilon_x (S_x - S_R)$ should be⁵ taken into account only in the cases where $S_x > S_R$.

Values of variable coefficients η_x and ϵ_x are determined from expression:

$$\eta_x = \frac{S_0}{S_x} \text{ and } \epsilon_x = \frac{S_x - S_R}{S_R - S_0}$$

⁵ Translator's Note: Mistake in the original, $S_R - S_R$.

⁶ Translator's Note: Mistake in the original, it is just ϵ .

Dimensions of the area S_R are being determined for a point with a maximum value P'_x .

Adjusted productivity values of alluvial deposits were computed from formula (5), in all cases where graphs of P'_x and the morphology of the deposits was suitable. Figure 6 compares graphs of P'_x computed from formula (2) with graphs of adjusted P'_x values from which the mean optimum productivity may be estimated. For Kulanchak Creek, the adjusted P'_x graph agrees fairly well with the theoretical graph. The results for creek V were less satisfactory. A deeper study of the complicated laws controlling the formation of alluvial deposits should be investigated further.

Figure 7 shows the results of computations of possible lead reserves (Q') in the Kulanchak district. The total reserves in this district may be estimated as equal to $n \cdot 10^3$ tons to a depth of 1 m. A detailed metallometric survey at a scale of 1:10,000 should be conducted on an area not less than 20 km². In 1958, a detailed survey was performed here on an area of some 0.5 km². As a result of this survey, a rich dispersion halo, more than 700 m long and a productivity of about 20,000 m² was discovered. No exploratory trenches and pits were excavated in this area.

Because of the inaccessibility of a considerable part of the Oygaing district, it was impossible to cover this district with a regular grid system of routes for the metallometric survey at a scale of 1:200,000 (figure 8). Detailed surveying and exploratory excavations indicated an insignificant lead ore occurrence in bedrock. This occurrence corresponds to a low-content alluvial deposit along the left lower tributary of Barkrak Creek. Much more promising are the upper reaches of left tributaries of the Koks River and in the middle reaches of the Tunduk Creek. There is no doubt that exploration should be pursued in areas where deposits were discovered. Previous estimates and conclusions are undoubtedly important for the planning of further prospecting here.

Voluminous data were secured from extensive metallometric surveys of the high mountainous region in the western part of the northern Tien-Shan. This data points to the following conclusions:

1. Metallometric surveys performed by testing alluvial and deluvial deposits associated with the drainage system in one area of about 3,000 km² led to the discovery of alluvial deposits of lead and several other metals. These flows are related to Badam Creek, Kulanchak, Oygaing and several smaller ore districts. The deposits are associated with lead dispersion halos and with bedrock ore occurrences.

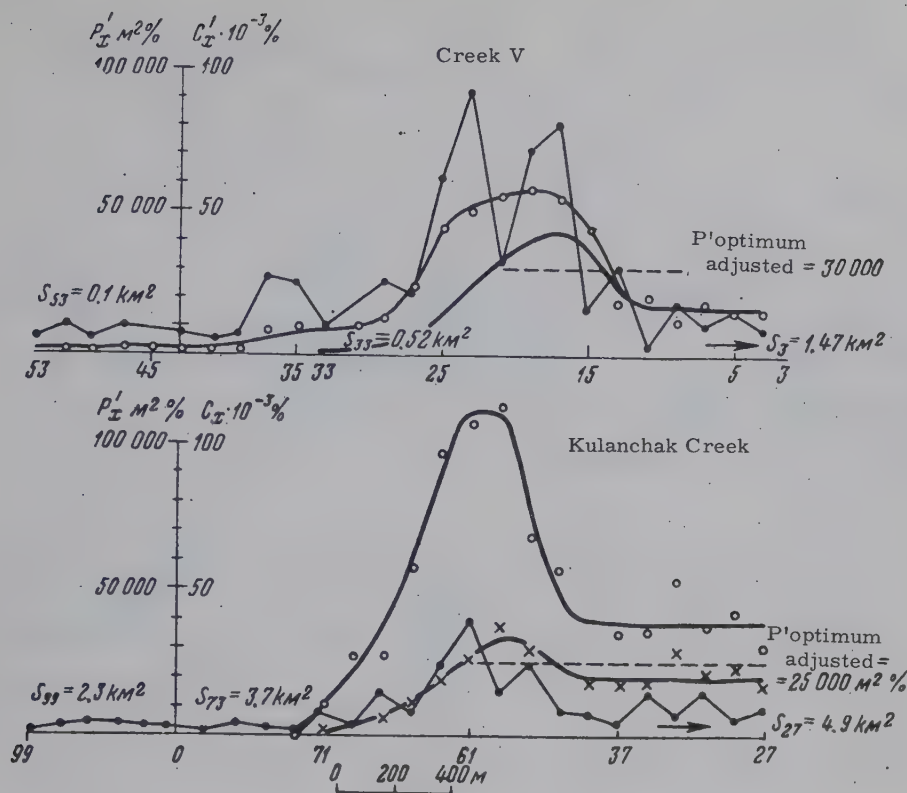


FIGURE 6. Graphs of the lead content and productivity of alluvial deposits

- curve C'_x
- curve $P'_x = C'_x \cdot S_x$
- curve of adjusted values of P'_x

To conduct reconnaissance metallometric surveys of alluvial deposits (along with far more detailed investigation of promising fields up to a scale of 1:10,000) costs only 20 percent as much as to cover the same territory with 1:50,000-scale areal metallometric surveys of dispersion halos, as is common in Kazakhstan and elsewhere in the U. S. S. R.

2. A quantitative analysis of survey results confirmed the relationship between the metal content in an alluvial deposit and the following factors: 1) basin area and 2) richness and extent of dispersion halos within this basin. Hence, the authors may estimate the productivity of the deposit and of the possible metal reserves to a depth of 1 m within a given erosion basin. The value $Q' = n \cdot 10^3$ indicates the potential. Naturally, this estimate of metal reserves leaves questions open with respect to ore quality and the morphology of ore bodies. Further investigations may finally lead to unfavorable conclusions. However, an opportunity to estimate the possibilities of ore districts by investigation of

alluvial deposits is of paramount importance for the objective planning of further research and prospecting. Therefore such a metallometric survey may be very effective in mountainous regions, where short-term investigations may uncover major eroded ore deposits. In certain regions where there are abundant traces of old mining operations, the search may be hindered by placers.

3. A comparison of the results of schlich-test and metallometric surveys, both conducted in the same territory, shows that the metallometric surveys have indisputed advantages in the search for lead ores, and also for mercury, molybdenum, and possibly cobalt. Results were similar for tin and bismuth. Data obtained for copper, nickel, and niobium are inadequate for definite conclusions; it should be mentioned, however, that the presence of niobium was indicated by metallometry, but not recorded by schlich testing. Large tungsten deposits cannot be missed by the metallometric surveying. Schlich testing is favored in prospecting for gold, platinum, monazite, and diamonds.

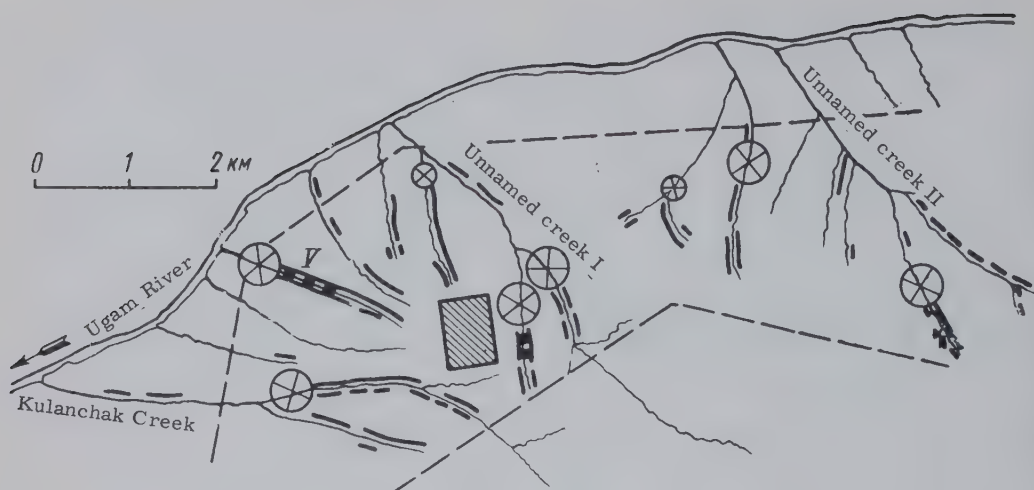


FIGURE 7. Sketch map showing results of the metallometric survey of the Kulanchak district

- $I/$ - routes along the alluvial deposits
 - lead content from 5 to $10 \cdot 10^{-3}$ percent
 - the same from 10 to $30 \cdot 10^{-3}$ percent
 - the same $30 \cdot 10^{-3}$ percent
 - lead reserves in the erosion basin to a depth of 1 m of about $n \cdot 10$ tons

- the same, of about $n \cdot 10^{-2}$
 - area covered by a detailed metallometric survey
 - boundary of the zone characterized by ore possibilities
 - Lower Carboniferous limestones

It should be stated regarding application of the hydrochemical method in mountainous regions that, although no data are available for this area which could be compared with the results of metallometry, general geologic considerations indicate fallacious reasoning in planning to base prospecting on the testing of the soluble phase of alluvia. Some metals are undoubtedly found in waters of rivers and streamlets, but metals are mainly concentrated in solid products of erosion [7]. G. B. Sveshnikov [4] presented the following data for waters of streamlets crossing the areas with dispersion halos and flows related to polymetallic deposits of the Rudnyy Altay, a high mountainous region with conditions similar to the area studied: the copper and lead content of the water does not exceed $1.1 - 1.6 \cdot 10^{-5}$ percent. The zinc content does not exceed $1.25 \cdot 10^{-5}$ percent. Let us compare these data with the following amounts of metals in alluvial deposits determined as a result of our work: lead and zinc, 0.2 to 0.3 percent, copper, 0.09 percent. Sveshnikov comes to the further conclusion that "anomalous amounts of copper and lead are found in streams located not farther than 300 to 500 m from ore deposits" [4, p. 97]. This should be compared again with alluvial halos of 3.5 to 4 km long, which we observed in the field. According to data obtained by V. V. Polikarpochkin and others [4], as a result of simultaneous investigations of the solid and soluble phases of the alluvial deposits in the Transbaikalian region, a conclusion suggests itself con-

cerning the advantages of such investigations in prospecting of alluvial deposits.⁷ Considering the technical and economic advantages of metallometry, the hydrochemical method should be rated inefficient in mountainous regions.

4. Further elaboration of metallometric surveying techniques for alluvial deposits is needed, primarily for interpretations of results. In particular, more data are needed on its use for a wide range of elements under various climatic and geomorphological conditions and in different geologic and geochemical settings. More precise spectrographic analysis is badly needed in prospecting alluvial deposits.

5. On the basis of experience, it is recommended that metallometric prospecting be applied extensively in mountainous regions. The work pattern should be: surveys initially conducted at a scale of $1:200,000$; samples taken from fine fractions of alluvial and deluvial deposits at intervals of 500 (250 m) and one

⁷Authors of the work [4] admitted unjustified deviations from the universally adopted terminology: to alluvial deposits they applied the term "halo" and sometimes "train of halo." [Translator's note: These authors use "dispersion flows" for alluvial deposits.]

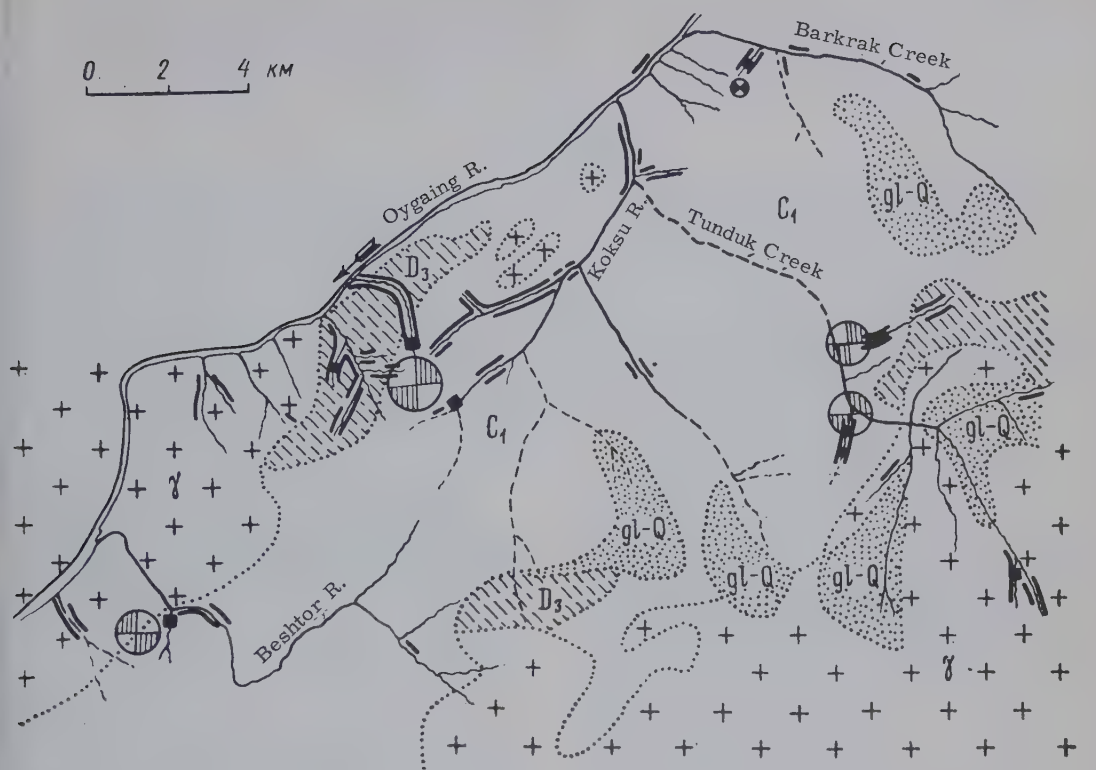


FIGURE 8. Sketch map showing results of the metallometric survey of the Oygaing District

- | | | | |
|--|---|--|--|
| | - routes along the alluvial deposits | | - the same, of about $n \cdot 10^3$ tons |
| | - lead content from 5 to $10 \cdot 10^{-3}$ percent | | - the same, of about $n \cdot 10$ tons; confirmed by a detailed metallometric survey |
| | - lead content from 10 to $20 \cdot 10^{-3}$ percent | | - older Quaternary glacial deposits |
| | - lead content over $20 \cdot 10^{-3}$ percent | | - Lower Carboniferous limestones |
| | - Stream beds not subjected to sampling | | - Upper Devonian limestones and sandstones |
| | - lead reserves in the erosion basin to a depth of 1 m of about $n \cdot 10^2$ tons | | - Upper Variscian granitoids |

density sample for each square kilometer in the territory under investigation. At this stage, samples should be processed, analyzed for 30 elements and subjected to determination of magnetic susceptibility, in accord with current instruction [2].

In the second stage, the areas in which ore possibilities were discovered should be subjected to sampling at intervals of 100 m, with about 10 points sampled on each square kilometer. If necessary, areal metallometric surveys should be conducted at a scale of 1:50,000 with a grid of 500 by 50 m. The results of the second stage of work will suffice for computation of the possibilities of ore districts.

We share V.I. Krasnikov's opinion [3] that metallometric prospecting of alluvial deposits must cover all areas with ore possibilities not previously subject to geochemical prospecting. We think that, in prospecting in mountainous and dissected regions, complex investigations of the drainage system should be limited to a combined schlich-metallometric survey. The hydrochemical method should be applied only to deep ground-water levels in covered regions.

It is essential to organize metallometric surveys in inaccessible mountainous regions of Kazakhstan during the current seven-year period: in the Transili and Dzhungar-Alatau, in the Ketmen Ridge and Tarbagatay, in mountainous Altay, in Kirgizia, and in other Central

Asian republics, as well as in mountainous regions in the east and northeast parts of Asian U. S. S. R. The application of this method

alone will secure new factual data on mineral reserves and raw material resources of these regions most quickly and economically.

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THERMAL PROPERTIES OF MESOZOIC AND CENOZOIC SEDIMENTS IN THE EASTERN PART OF THE WEST SIBERIAN LOWLAND¹

by

V.A. Koshlyak²

ABSTRACT

Thermal borehole logging of the eastern part of the West-Siberian lowlands shows a dependable correspondence between geologic features and thermal gradients. After comparing logging data from various depths up to 2,900 m the author concludes that major basement structures and all except the deepest ground water horizons will be revealed in logging data taken from relatively shallow boreholes, such as those drilled for surveying and stratigraphic purposes. This discovery prompts the author to recommend that thermal logging be conducted in such boreholes as a very cheap method of determining deep structures, especially since they lead to important oil and gas discoveries. --A. Eustus

* * *

In recent years the study of the nature of natural heat distribution at various depths has acquired increasing importance for prospecting and exploratory work.

This article presents the results of geothermal investigations in boreholes drilled in the eastern part of the West-Siberian Lowland.

Of the many factors controlling the geothermal regime of the Mesozoic and Cenozoic sediments covering this lowland, the following heat flows are of the greatest importance: 1) those coming from depth (magma); 2) those controlled by the petrographic composition of the foundation; 3) those resulting from a hydrogeologic factor (heat transferred by ground water). These factors are predominant where no additional heat sources are found in the sedimentary blanket, such as heat resulting from the processes of radioactive disintegration in Mesozoic and Cenozoic sediments; or where such heat sources are insignificant.

Paleozoic rocks of the basement part of the West-Siberian Lowland, overlain by the Mesozoic and Cenozoic, have been found at relatively shallow depths by the majority of deep borehole probes, the results of which have not yet, on the whole, been sufficiently well studied. In the Central Ob' area, Paleozoic rocks consist of displaced weakly metamorphosed sediments as well as extrusive and intrusive formations.

The Lower Carboniferous sedimentary rocks were penetrated by the Chulym borehole 1-r at

a depth of 2,715 m. In the Kolpasheva area, the basement is made up of Middle Devonian rocks composed of intensively displaced slightly metamorphosed, fine-grained argillites, siltstones and sandstones. Similar rocks overlie the southern flanks of the Parabel' and Narym structures. In these areas the basement contains intrusive rocks of a granodiorite type also occurring in the crests and in the northern flanks. In the Pudino borehole 1-r, the pre-Jurassic foundation is made up of black, coaly, crevassed argillites. At the Nasino structure, sedimentary rock of the Lower(?) or Middle Jurassic complex are underlain by quartz porphyries. The Jurassic foundation in the area of the Kass and Yeluguy bore holes is built of somewhat different rocks. According to the data obtained from the first borehole, Paleozoic strata are represented by alternating sandstones and argillites containing layers of conglomerates and breccia. The Yalaguy borehole 1-r, in addition to sandstones and siltstones, penetrated limestones and dolomites.

A geoisotherm map (fig. 1) shows that the Kolpashevo, Narym, and Parabel' and Pudino areas lie in a high heat-field zone. From the schematic structure it is seen that these areas are characterized by a relatively high basement underlying Mesozoic and Cenozoic rocks. According to the schematic tectonic map constructed by a group of geologists under the supervision of V. P. Kazarinov, this region corresponds to the Parabel' arch (a structure of the first order).

Maximal values of geoisotherms were found in the area of Narym-Parabel' structures (the 3.5°C/100m - isotherm), where the basement rocks, granodiorites, were found at depths less than 2,600 m. Values of geoisotherms decrease towards the Ust' Chizhay, Kass, and Tegul' depressions. Another increase in geothermal gradient averages (the 3.0°C/100m - isotherm) occurs east from the Maksimkin ravine, in the direction of the Kass borehole

¹Translated from *Termal'nyye issledovaniya otlozheniy Mezo-Kaynozoya vostochnoy chasti Zapadno-Sibirskoy nizmennosti*: Sovetskaya geologiya, no. 5, 1960, pp. 97-106.

²Kolpashev Expedition.

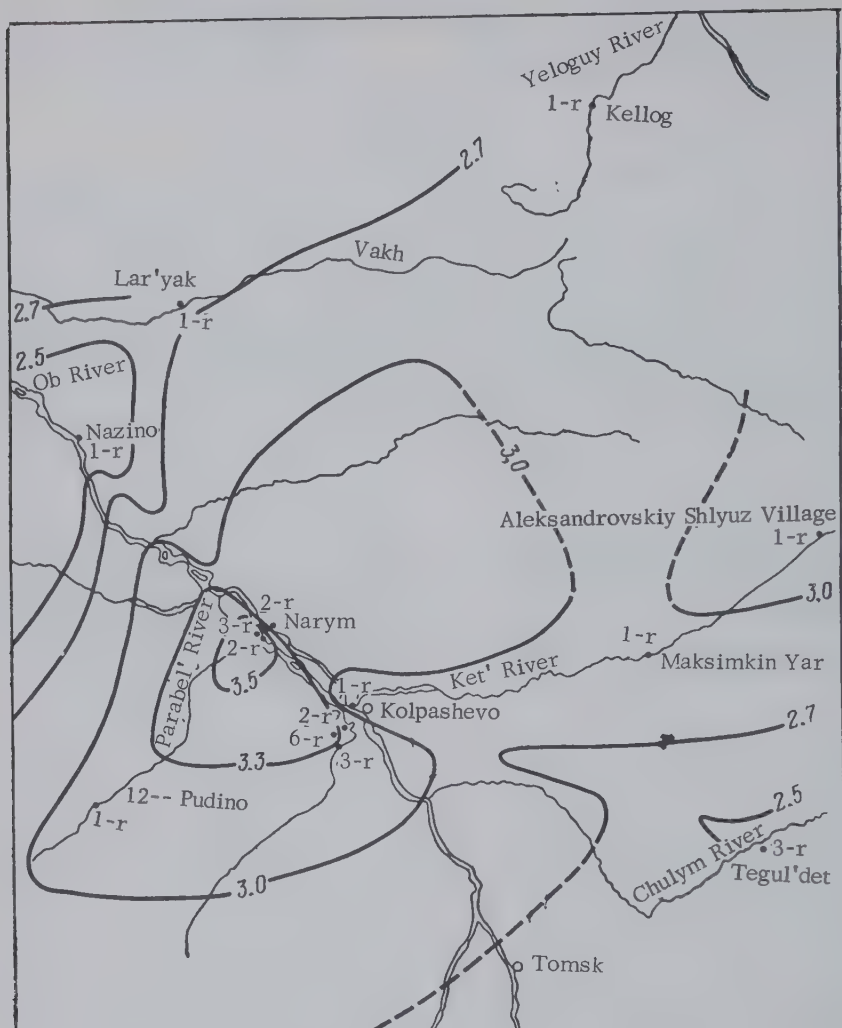


FIGURE 1. Schematic map showing geoisotherms (1 degree for each 100 m) in the eastern part of the West Siberian Lowland.

(Aleksandrovskiy Shlyuz village), where the Paleozoic basement was penetrated at a depth of 1,678m.

An anomalous low geothermal gradient is observed in the Nazino borehole 1-r located in the extreme southeastern periclinal part of the Nazino structure. Here the foundation was penetrated at a depth of 2,609 m, and was found to be composed of quartz porphyries. Thermal investigations were twice made in boreholes: after 52 and after 90 days, the average geothermal gradient being established at $0.29^{\circ}\text{C}/100$ [$G_{av} = 0.29^{\circ}\text{C}/\text{m}$]. It is of interest that temperatures increase sharply in the Jurassic sediments. The measurement of temperature in the borehole at various depths yielded the following results:

Depth in m	Temperature in $^{\circ}\text{C}$
2,460	96
2,430	93
2,412	91.5
2,357	87

Table 1 presents data on the depth to the foundation, values of geothermal gradients and intervals of depth from 1,000 to 1,500 m.

The schematic profile of isotherms along the Kolpashevo-Parabel'-Narym-Nazino line (fig. 2) clearly shows the relationship between the geologic setting and the nature of the distribution of natural temperatures along the borehole sections. The isotherms quite definitely follow the basement relief at the Kolpashevo and Narym-Nazino structures. This relation is

TABLE 1. Values of geothermal gradients and intervals of depth between 1,000 and 1,500 m

Areas borehole	Number of boreholes	Depth to basement in meters	Basement rocks	Temp. at 1,500 m, and 1,000 m* and difference	Geothermal gradient, C°/100 M	Geothermal interval, m/C°
Pudino borehole	1-r	2945	Argillites, bituminous, fissured	53.3-37.6 15.7	3.1	31.8
AREAS Kolpa-shevo	1-r	Basement not reached		43.1-29.1 14.0	2.8	35.7
	2-r	2870	Alternating argillites, siltstones and sandstones, dislocated, slightly metamorphosed	47.5-31.4 16.1	3.2	31.0
	3-r	2779		49.2-33.3 15.9	3.2	31.4
	6-r	2730		49.6-32.5 17.1	3.4	29.2
	2-r	2600		51.1-39.1 12.0	2.4	41.6
	3-r	2595	Granodiorites	60.2-41.9 18.3	3.7	27.3
Narym	2-r	2726		55.4-38.9 16.5	3.3	30.3
Nazino	1-r	2609	Quartz porphyries	50.9-39.9 11.0	2.2	45.4
Chulym	1-r	2715	Argillites siltstones	33.3-19.9 13.4	2.7	37.3
Maksim-kin-Ravine	1-r	Basement not reached	-	38.0-23.2 14.8	2.9	33.8
Lar'yak	1-r			39.4-26.1 13.3	2.6	36.6
Yelaguy	1-r	1468	Alternating argillites, siltstones dolomites, limestones and sandstones.	38.4-24.8 13.6	2.7	36.7
Kass	1-r	1678	Alternating sandstones and argillites with layers of conglomerate and breccia.	36.2-20.4 15.8	3.1	31.6

*Boundaries of interval studied.

seen most clearly in deeper parts of the profile, where temperatures in Jurassic rocks and the lowermost Lower Cretaceous sediments were used. Insufficient data on rock temperature of the upper part of the profile somewhat distorts the general geoisotherms pattern. The Parabel' anticline is separated from the Alexandrovskiy anticline by the Ust'-Chizhap depression, causing an understandable sharp drop of isotherms to the north Narym boreholes 2-r. North of borehole 2-r, borehole 4-r was drilled to a depth of 3,000 m but did not reach the basement.

Toward the Nazino local uplift borehole 1-r, the isotherms rise in value. This is most distinctly seen in the upper and lower beds. In the middle part of the section, the curves flatten somewhat. At the Parabel' structure (see fig. 2), isotherms change with depth towards the northern flank of the structure. This change is apparently caused by a difference in the composition of the basement rocks. Bore-

hole 2-r revealed the basement to be made up of sedimentary rocks whose thermal conductivity is much lower than that of the intrusive [extrusive? - izverzhennyye] rocks in the anticline and in its northern limb (boreholes 1-r and 3-r). It is natural that a deep heat flow, encountering rocks with a low thermal conductivity; in this it deflects towards the intrusive rocks. An additional heat flow appears as a result of the energy of radioactive decay. The highest concentration of radioactive elements has been recorded in acid intrusive rocks. The decay of these elements leads to heat production averaging $5.6 \pm 1.7 \cdot 10^6$ cal/gm-yr [9]. An increased radioactivity of the basement of the eastern part of the West Siberian Lowland is confirmed by the data of measurements of gamma activity. The intensity of natural gamma radiation in borehole 3-r (Parabel') at a depth of 2,570 m attains 27 MC/hour. Increased natural gamma activity of Jurassic sedimentary rocks overlying graniorites is apparently caused by the influence of intrusive[?] rocks. It

is possible that the contact between the intrusive[?] and sedimentary rocks follows the deep-seated fracture shown on the profile (see fig. 2). However, the problem of the reflection of change of the isotherm form has as yet not been sufficiently studied.

The presence of intrusive[?] rocks in the crest and on the northern flanks, as well as the occurrence of intensively dislocated Paleozoic sedimentary rocks on the southern flanks of the Narym and Parabel' structures, is apparently associated with intensive tectonic movements developed in the beginning of the Jurassic. The intensity of tectonic movements was somewhat lower on the side of Kolpashevo group of uplifts. However, an increase with depth of the geothermal gradient in borehole 2-r (South-Kolpashevo structure), where geothermal readings were taken in Mesozoic and part of the Paleozoic rocks (130 m), is caused by the proximity to an additional source of heat. In all probability, such a source may be represented by intrusive[?] rocks which did not break through metamorphosed Paleozoic rocks.

In our opinion, the sedimentary complex of Jurassic age, characterized by a high thermal resistivity, is underlain by slightly metamorphosed Paleozoic rocks having a somewhat higher thermal conductivity. The latter rocks rest on igneous formations radiating additional heat. In this case, the geothermal gradient should change as follows: it would increase downward along the boreholes, reaching a maximum at the Jurassic-Paleozoic interface. The increase in the gradient is caused by high values of thermal resistivity of Jurassic sedimentary rocks. The gradient should decrease in Paleozoic rocks, explainable by somewhat higher thermal properties for metamorphic for metamorphic rocks. The occurrence of intrusions beneath these Paleozoic rocks should produce a new increase in gradient. The intensity of this increase would be proportional to the distance from the source of heat, i.e., from intrusive rocks.

Table 2 presents geothermal gradient data for the lower part of the profile.

TABLE 2.

Interval	Age of rocks	Average values of	
		Geothermal gradient C°/100 m	Geothermal interval m/C°
2500-2600	Middle Jurassic	5.27	19
2600-2700		6.8	14.7
2700-2800	Middle Jurassic-Paleozoic	4.5	22.3
2800-2900	Paleozoic-Jurassic	4.55	22
2900-2990	Paleozoic	3.73	15.7

It should be noted, however, that the gradient decreases in the lower Middle Jurassic. This

is apparently explained by the lower thermal resistivity of sediments here. The electric log for this interval reveals apparently low resistivities (as compared with the overlying Middle Jurassic).

Investigations of boreholes (1-r, 2-r, 3-r, and 6-r) on the south Kolpashevo uplift make it possible to consider that the distribution of the thermal field is controlled by the geologic setting of the structure. The gradient values in boreholes 2-r and 3-r are almost equal within the interval from 1000 to 1500 m (see table 1), both boreholes lying on the flanks of the structure. Further north (town of Kolpashevo), where the structure is more deep-seated, the geothermal gradient decreases to 2.8° C/100 m. This decrease is associated with the northward dip of the basement.

In the Maksimkin-Ravine borehole, the geothermal gradient increases gradually to a depth of 2,000 m. From this depth the gradient increases sharply to 4.5° C/100 m in the interval from 2,000 to 2,400 m. Such an increase in the geothermal gradient [6] occurs where the underlying rocks differ lithologically from the overlying rocks and have different thermal properties. The steepness of the curve appears to be in inverse proportion to depth of rocks of different thermal properties. Mesozoic and Cenozoic sediments in the Ket' Tym depression are assumed to be 3,000 m thick. Boreholes penetrated Middle Jurassic rocks at a depth of 2,500 m.

The Lar'yak borehole, located in the north central Ob' region, penetrated Middle Jurassic deposits at a depth of 2,800 m. By analyzing facies and thicknesses, F.G. Gurari [3] outlines the Lar'yak depression, whose existence is confirmed by geothermal investigations. A graph of the change of the geothermal gradient with depth ($G = f(z)$) indicates a slight increase in the geothermal gradient. The investigations were conducted to a depth of 2,768 m, with an average gradient of 3.5° C/100 m, from 2,000 to 2,758 m; i.e., it is lower here than in borehole 3-r (Parabel') within the 1,000-to-1,500 m interval. Judging from the geothermal gradient a thickness of 3,200 or 3,500 m may be assumed for the sedimentary Mesozoic-Cenozoic blanket in the Lar'yak Depression.

An entirely different pattern of changes in the geothermal gradient is observed in the Chulym borehole (Telgul'det village). The gradient gradually increases to 3.3° C/100 m at a depth of 2,000 m. From 2,000 to 2,770 m the gradient decreases to 2.9° C/100 m. This corresponds to a decrease in the thermal resistivity of Jurassic and Paleozoic rocks, as well as with the absence of the heat source. This permits the conclusion that crystalline rocks lie at depths exceeding 3,000 m. This agrees with the results of a geophysical survey

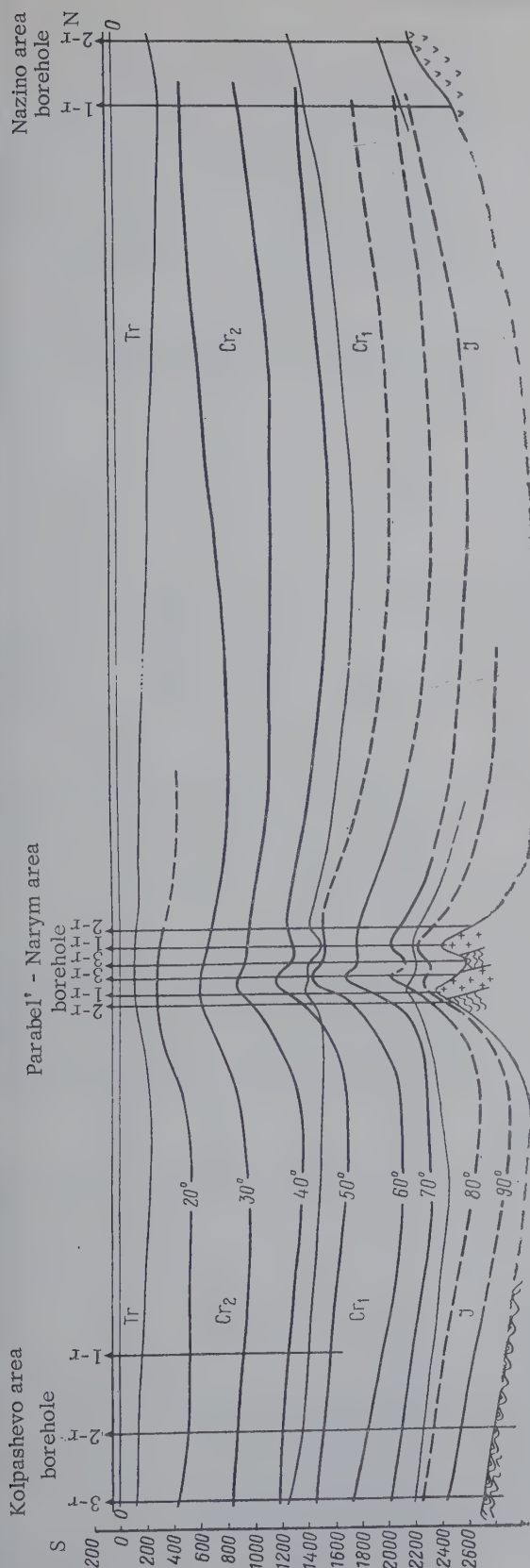


FIGURE 2. Profile of isotherms within the West Siberian Lowland

- isotherms
- stratigraphic boundaries
- sedimentary rocks of Paleozoic age
- intrusive rocks
- extrusives

performed in this area.

The active flow of ground water from the areas of supply greatly influences the thermal regime. In the eastern part of the basin, the lower horizon of ground water with low mineralization of the sodium-bicarbonate type trends upward from east to west. For example, in Maksimkin-Ravine borehole 1-r, this horizon lies in the Jurassic deposits at a depth of 2, 150 to 2, 221 m. In the Kolpashevo area it lies at a depth 1710 to 1790 m in Hauterivian and Barremian deposits. In the Lar'yak area (borehole 1-r) it is encountered at a depth of 1, 100 to 1, 500 m. Ground-water mineralization increases uniformly downward toward the central part of the West-Siberian Basin. Wide distribution of waters of the sodium-bicarbonate type indicates regional erosion of considerable part of the Mesozoic and Cenozoic sediments which is apparently explained by the fact that during the long time interval this area underwent a relative uplift. Where water circulation is restricted, ground-water mineralization increases rapidly at depth and waters of the chlorine-calcium type appear. The mineralization associated with Jurassic sediments is characterized by the following values: in Kolpashevo, 45 gr/liter and up, in the Maksimkin-Yar borehole 1-r 54 gr/liter.

A sharp decrease of isotherm values is observed from Kolpashevo in the west to Aleksandrovskiy Shlyuz in the east. It is best seen in the upper part of the profile, where structures were most intensively eroded. Lower in the profile and in the western part of the lowland, the isotherms pattern mainly reflects the tectonic framework. The rise in isotherm values from Kolpashevo to Pudino, where the foundation is 100 m lower, may be explained by the introduction of heat by warm waters from the Oms'k Depression.

Figure 3 (a) presents a schematic subsurface map of isotherms at a depth of 1, 000 m, corresponding to the lower part of the Aptian-Albian-Cenomanian complex. The pattern of isotherms indicates the direction of ground-water flow from the east and southeast of the lowland. The Kolpashevo uplift coincides with the eroded zone.

Figure 3 (b) presents an analogous schematic subsurface map of isotherms corresponding to the lowermost part of the Lower Cretaceous. The nature of isotherms is the same, but the intensity of the flow of ground waters is considerably less, although the direction of the movement remains the same. The Kilpashevo uplift lies within the zone of little temperature change. A new decrease in temperatures is observed in the Nazino area (borehole 1-r). N. N. Rostovtsev [5] indicates that the ground-water flows from the Maksimkin Ravine toward Kolpashevo and farther on toward the Lar'yak and Pokur areas. It is possible this flow bends

to the east around the Parable'-Narym group of structures and then bifurcates, one branch flowing almost due north towards the Lar'yak area, the second branch passing through the Ust' Chizhap downwarp and toward the Kanta-Mansi depression. This hypothesis explains why the geothermal gradient and temperatures are low in Narym borehole 2-r, located on the northern flank of the structure. However, the question is not settled because of the absence of deep boreholes along the Narym-Nazino line.

Mineralization of ground water generally increases with depth, attaining maximal values in the Jurassic sediments of the Kilpashevo and Maksimkin-Ravine areas (table 3). Irregular

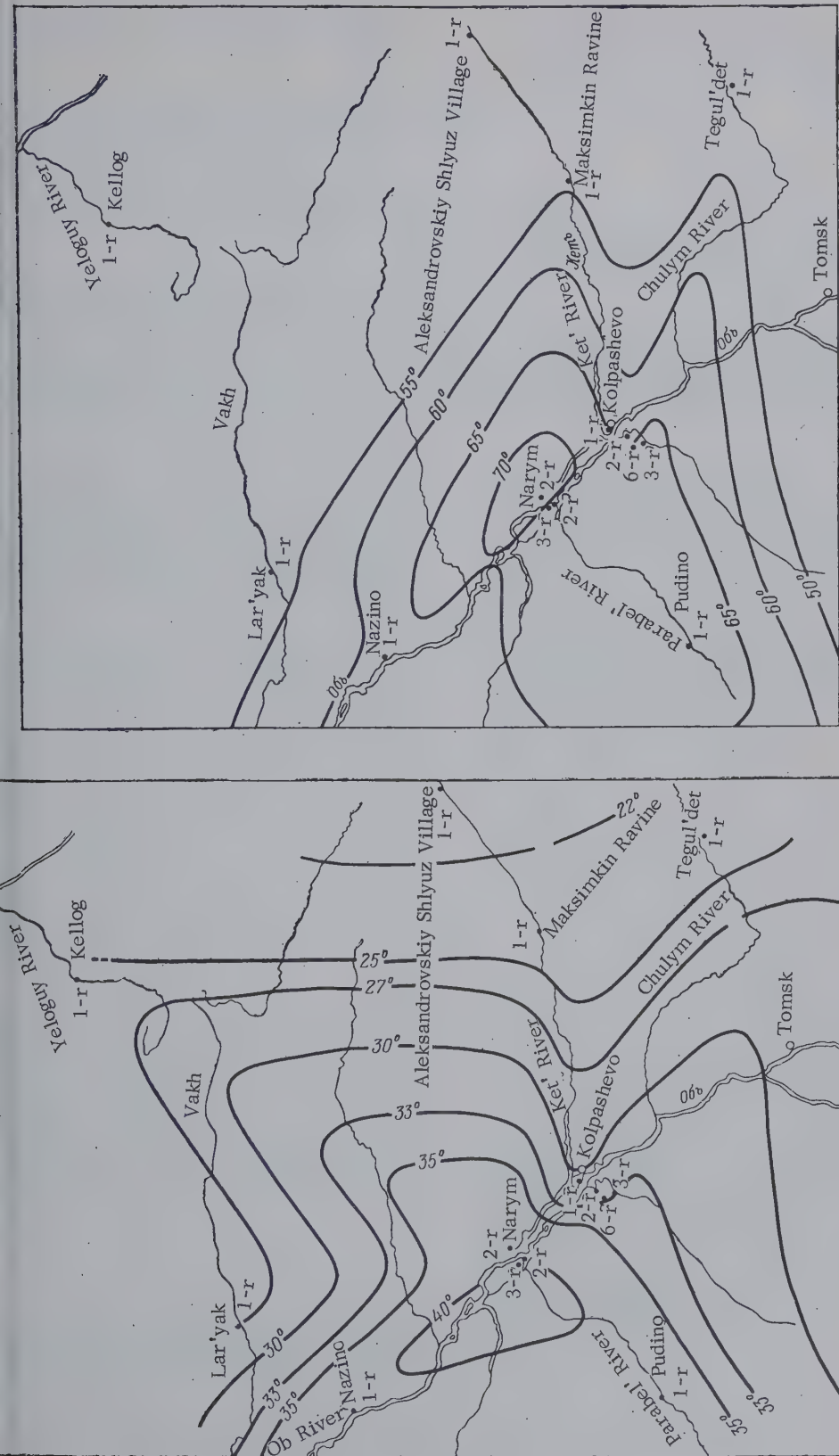
TABLE 3.

Area, borehole	Depth m	Mineralization, gr/L
Kolpashevo depression	2094	4.5
	2387	15.3
	2455	49.8
	2668	36.1
	2709	43.5
The Maksimkin-Ravine borehole 1-r	2042	3.0
	2100	9.0
	2210	16.9
	2409	54.0

variations in the mineralization of ground water with depth, where aquifers lie relatively close to one another, bear witness to the fact that the aquifers are isolated from each other. We present for illustration data on variations in the mineralization in boreholes of the Maksimkin-Ravine and Kolpashevo areas [5].

The occurrence of isolated aquifers of different temperatures such as those of the lowermost Lower Cretaceous and Jurassic sediments, indicates difficulties in the investigations. Thus, it is quite natural that with a very limited number of temperature measurements, profiles for depths exceeding 2, 000 m may not provide hydrogeologic data for a specific aquifer.

The study of the geothermal regime is of great importance for estimating of oil and gas reserves. Temperature is one of the principal factors in the process of the transformation of organic remains into oil and in the process of fluid migration in rocks. Many investigators have come to the conclusion that the oil depends on geothermal regime [5]. Geothermal investigations carried out in the eastern part of the West Siberian Lowland provided interesting data on the geology and hydrogeology of this territory. We plotted graphs which show that the thermal effect is maintained not only near the basement, but also in the upper part of the section. This makes it possible to recommend temperature measurements in boreholes drilled for surveying and stratigraphic purposes. The simplicity and cheapness of the method make it easy to use



a - depth of 1,000 m

b - depth of 2,000 m

FIGURE 3. Schematic subsurface maps of isotherms at depths

geothermy to yield very valuable information on deep-seated tectonic settings. Still more favorable conditions derive from the fact that the Tertiary and Upper Cretaceous sediments penetrated by boreholes are mostly represented by clayey deposits.

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ABSOLUTE AGE OF MESOZOIC AND CENOZOIC VOLCANIC AND INTRUSIVE ROCKS IN THE OLGA-TETYUKHINO AREA¹

by

Ye.V. Bykovskaya, N.I. Polevaya and N.S. Podgornaya

REVIEWER'S NOTE

Looks good although of limited interest.

* * *

ABSTRACT

Complex interbedded formations in the Soviet Far East provide a testing ground for various dating methods, chiefly paleontologic and the argon-potassium method. The Olga-Tetyukhino area offers alternations of various extrusives chiefly tuffaceous and sedimentary deposits, mainly limestones and siltstones, rich in Mesozoic and Cenozoic fauna. The authors find the biologic and radioactive methods in close harmony on results, provided the proper corrections are made. Detailed stratigraphic tables are included. --A. Eustus.

* * *

The Olga-Tetyukhino area is located in the coastal zone of the Tetyukhino trough [1]. Most of this territory is made up of a Mesozoic and Cenozoic complex of volcanic and intrusive rocks. Determination of the absolute age of extrusive rocks in this area is facilitated by wide distribution of volcanic and volcanic-sedimentary rocks, mostly acidic and intermediate, i.e., having a relatively high potassium content. In addition, many volcanic-sedimentary formations may be rather reliably dated on biostratigraphic ground. A distinct chronological relation is commonly revealed between intrusive and extrusive rocks, beginning with the second half of the Late Cretaceous and including the late Paleogene, magmatic activity was practically continuous in the Olga-Tetyukhino area. For 30 or 40 million years, intrusive activity repeatedly alternated with extrusive activity. Naturally time intervals between them should be insignificant, probably of the same order as the errors implicit in the argon method. Therefore, this work is a serious test of the argon method.

We have attempted to subdivide chronologically the Mesozoic and Cenozoic intrusive and extrusive rocks. Figure 1 is a schematic map of the area under investigation, showing the location of granitoid intrusions and indicating the places of sampling of intrusive rocks for the analysis. The profile of the sedimentary-volcanic rocks (figure 2) also shows locations of sampling and presents the results of the age determination in millions of years.

The Late Cretaceous volcanic cycle [2, 3] began with the eruption of intermediate extrusives (the Bazovoy formation) and ended with the appearance of acidic extrusives and their tuffs (the Kisinskaya and Monastyrka formations). In the Avvakumovka River basin, the porphyries of the Bazovoy formation rest on sedimentary rocks with fauna determined by V.N. Vereshchagin as *Exogyra* ex. gr. *flabellata* [flagellata?] Goldf., and *E. cg. localis* Mordv. var. *subtipica* Mordv. of Albian-Cenomanian age. In the basin of the Sibaygou River, according to R.I. Sokolov's data, porphyries directly overlie sedimentary rocks containing Nikanskaya flora.

Samples of porphyries for absolute-age determination were taken from outcrops exposed along the Bazovoy spring, a right-side tributary of the Sibaygou River (specimen 155) and on the coast near Cape Skalistyy (specimen 30a)

Within the mass of overlying acid extrusives, there occurs the tuffaceous-sedimentary Arzamas formation dated as upper-Senonian on the basis of abundant plant remains:³ *Asplenium foresteri* Deb. et Ett., *Cladophlebis septentrionalis* Holl., *C. frigida* (Heer) Jen., *Ligodium* cf. *kaulfussii* Heer, *Saccoloma gardneri* (Lesq.) Knowlt., *Equisetites* sp., *Nilssonina* sp., *Pinites* sp., *Pinus* sp., *Taxodium* sp., *Thuja cretacea* Newb., *Tumion gracillimum* Holl., *Dicotilophyllum* sp., *Populus* sp., *Paraengelhardtia* sp., *Platanus cuneifolia* Brongn., *Paliurus* sp., *Ziziphus* sp., *Trapa microphylla* Lesq., *Corylus jeliseevii* Krysh., *Trachodendroides Pichardsonii* [Richardsonii?] (Hr.) Krysh., *Norden-skioldia borealis* Heer, *Viburnum tetyuchensis* Krysh., *V. lesquereuzii* Ward. var. *longifolium*, *V. nudinervii* Baik.

Translated from *Kratkiye soobshcheniya - Absolyutnyy vozrast Mezo-Kaynozoyevskikh vulkanogennykh i intruzivnykh obrazovaniy Olga-Tetyukhinskogo rayona: Sovetskaya geologiya*, No. 5, 1960, pp. 107-115.

Union Geological Scientific Research Institute.

³Flora was determined by M.I. Borsuk, S.I. Nevolina, and B.M. Shtempel.

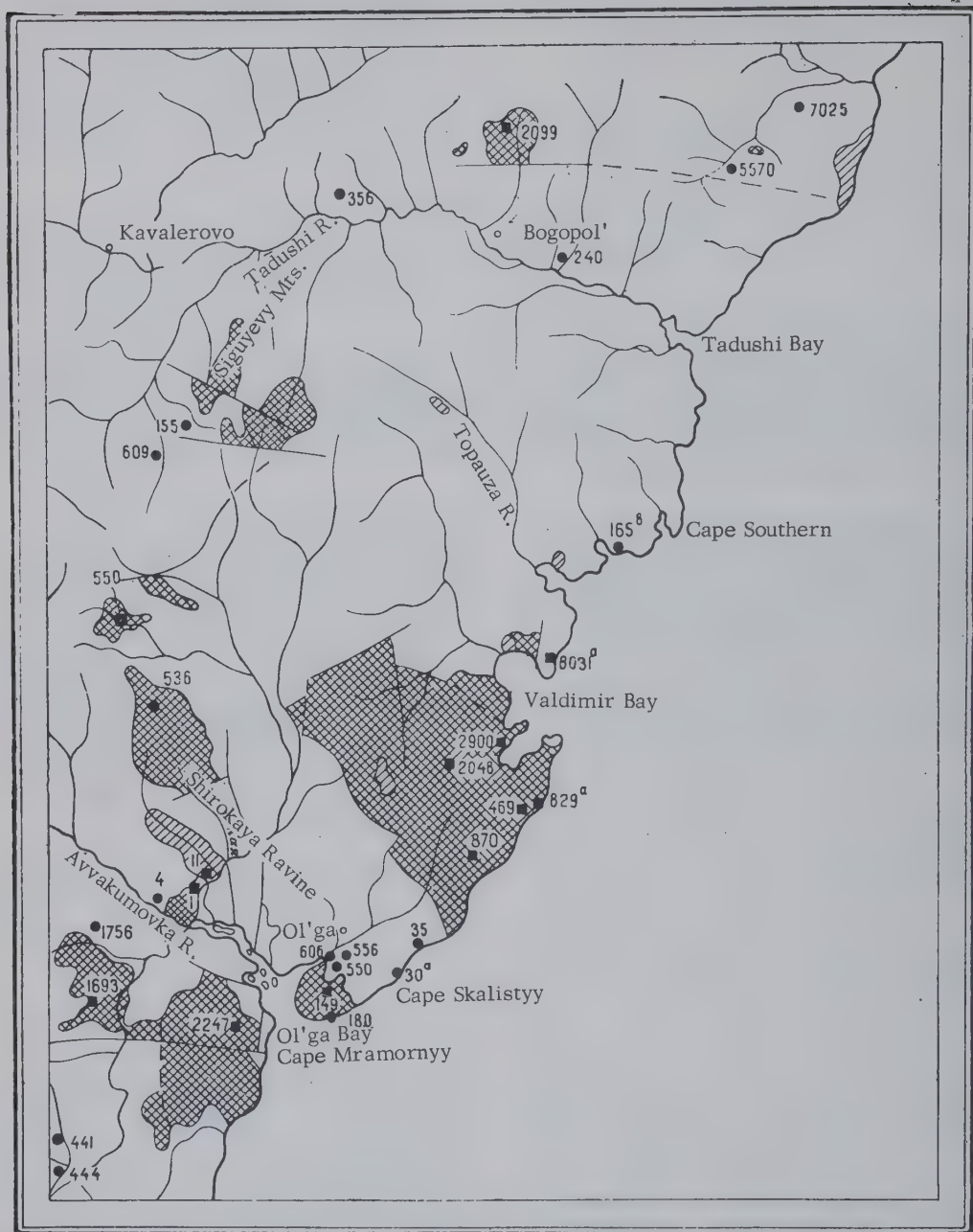







FIGURE 1. Map of the Olga-Tetyukhino area, of the Southern Maritime Province

FIGURE 1. Map of the Olga-Tetyukhino area of the Southern Maritime Province

- | | | | |
|---|-------------------------------|---|---|
|  | - tectonic contacts; |  | - points where samples of extrusive rocks were taken; |
|  | - Paleogene intrusions; |  | - the same for granitoids |
|  | - Late Cretaceous intrusions; | | |

	Age in million years	Sample number	Column	Thickness m	Description
Paleogene				600	The Brusilov formation: dacites, vitroliparites, ignimbrites, and tuffs
				150	The Vosnovskaya formation: siltstones, carbonaceous shales, ash tuffs, and argillites with flora
				200	The Suvorov formation: andesite-basalts, basalts, and occasionally tuffs
				300	The Topauza formation: tuffite conglomerates, siltstones interlayered with brown coals, layered tuffites and argillites with flora, tuffs of mixed composition
	48 50	240 7025		500	The Bogopol' formation: dacites, liparites, perlites, tuffs, and ignimbrites.
	50, 49 53 63	35, 441 356 4		1000-1700	The Siyanova formation: andesites, dacites (quartz porphyrites), quartz plagioporphyrries, tuff lavas, and tuffs containing layers of flora-bearing tuffites
Upper Cretaceous	72 60 70	5570 444 1756		800	The Monastyrka formation: quartz and felsitic porphyries, tuffs, and ignimbrites
				350	The Arzamazov formation: conglomerates, sandstones, siltstones, tuffites with flora, quartz porphyries and their tuffs.
	75 75 77 70	556 550 609 606		1000-1500	The Kisinskaya formation: quartz and dacite porphyries, tuffs, and occasionally, tuffites
	75 86	30 ^a 155		500-800	The Bazovoy formation: porphyries, their tuffs, and lava breccias
				1000	The Petrozuyevskaya formation: siltstones, tuffites, tuffite-sandstones, porphyries, and tuffs
					Sandstones with fauna and flora

FIGURE 2. Stratigraphic column of Mesozoic and Cenozoic rocks in the Ol'ga Tetyukhino area

Samples of quartz porphyries were taken both from the underlying Kisinskaya formation (specimens 606, 609, 550, and 556) underlying the Arzamas formation and from the overlying Monastyrka formation (specimens 444, 1756, and 5570).

The Paleogene volcanic rocks of this area were formed as a result of two volcanic cycles. The first began with andesites, dacites (specimen 4), quartz porphyries (specimen 356), tuff lavas of quartz porphyries (specimens 35 and 441), tuffs and tuffites of the Siyanova formation. Tuffites revealed imprints of the plants (*Tsuga schmidtiana* Palibin, *Glyptostrobus europaeus* (Brongn.) Heer, and *Pinus* sp.) indicating a Paleogene age for this formation. An analysis of a spherulite (specimen 165c), found in the coarse clastic tuffs of this formation, confirmed the external similarity of several varieties of acidic extrusives not only of those belonging to the Paleogene, but also to those of the Upper Cretaceous. Higher in the column, there occur spherulitic liparites (samples 240 and 7025), their tuffs, and tuff lavas of the Bogopol' formation. The cycle ends with tuffs of mixed composition, interlayered with tuffaceous-sedimentary deposits of Eocene age (the Topauz formation) characterized by a distinct flora.

The paleontologic evidence for the age of the overlying Paleogene extrusive-sedimentary rocks is based on numerous imprints of leaves in the Topauz formation. The Eocene flora complex is represented by the leaves: *Ginkgo adiantoides* (Unger) Heer, *Taxodium tinajorum* Heer, *Taxites olrikii* Heer, *Thuites ehrenswardii* Heer, *Alnus carpinoidea* Lesq., *Glyptostrobus europaeus* (Br.) Heer, *Sequoia* cf. *sternbergii* (Goepf.) Heer, *Zelkova furcinervis* Bors., *Pinus* cf. *hyperborea* Heer. The flora of this age is characterized by a decrease in the number of representatives of the species *Trochodendroides arcticus* (Heer) Berry and by the presence of the Upper Cretaceous forms *Grewiopsis* cf. *juconensis* Hollick.

The second upper Paleogene volcanic cycle includes basic extrusives and tuffs of the Suvorov formation, as well as acidic volcanic rocks of the Brusilov formation. The tuffs of the latter formation rest on sedimentary deposits of the Voznovskaya formation, characterized by both fauna and flora. Leaf imprints were found there resulting in a characteristic Oligocene flora complex: *Osmunda sachalinensis* Kryshch., *Pteris parschlugiana* Ung., *Sequoia langsdorfii* (Br.) Heer, *Metasequoia disticha* (Heer) Miki, *Glyptostrobus europaeus* Heer, *Taxodium tinajorum* Heer, *T. dubium* Heer, *Carpinus grandis* Ung., *Castanea* sp. cf. *C. ungerii* Heer, *Diospyros* sp. (cf. *D. anceps*?) Heer.

In the Bogopol' Village area, V. A. Zhilina found, within argillites of the Voznovskaya formation, the kernel of *Limnoscapha* (*Hyriopsis*)

sp.⁴ which confirms the Oligocene age of this formation. Hence, the acidic extrusives of the Bogopol' formation (samples 227, 240, and 7025), underlying the Eocene Topauza formation, must be relegated to the upper Paleocene.

Table 1 presents results of the absolute-age determination of extrusive rocks corresponding to their stratigraphic sequence, from younger to older. The determination of the potassium content in samples was made by L. V. Shashukova by the dipicrylamine method, argon was determined by the volumetric method according to E. K. Gerling [4]. All absolute-age determinations, except those marked with an asterisk in tables, were accompanied by the isotope analysis of separated argon. Age computations were made using the formula:

$$\frac{mAr^{40}}{m'K^{40}} = \frac{\lambda_K}{\lambda_K + \lambda_\beta} \left[e^{(\lambda_K + \lambda_\beta)t} - 1 \right],$$

where t denotes the age in millions of years;

$$\frac{mAr^{40}}{m'Ar^{40}}$$

is an experimentally established ratio between the amounts of argon and potassium in a sample in grams;

λ_K denotes constant K of disintegration K^{40} , equaling $0.557 \cdot 10^{-10}$ years⁻¹(5).

λ_β denotes constant β of potassium disintegration equaling $4.72 \cdot 10^{-10}$ years⁻¹(B)

The content of K^{40} in the potassium isotopes mixture was determined by the relative abundance of this isotope established by Nier [11] as equaling 0.0119 percent.

In published works on the age determination of igneous rocks of Sikhote-Alin' [6, 7, 8, and 9], other constants were used in the computation of age. Therefore, all previously published data after recalculation will indicate an age greater by some 10 percent. The necessity for accepting new values for constants of disintegration was substantiated in a recent work by Gerling [5].

Late Cretaceous and Paleogene intrusive activity in the Ol'ga-Tetyukhino area was not less intensive than the extrusive one and also took place in many stages.

To the Late Cretaceous also belong intrusions of the Sudno Mountain, Shyrokaya ravine, diorite xenoliths in the Vladimir massif, and somewhat younger intrusions of the Siguyevy

⁴The determination of this fauna was made by G. G. Martinson.

TABLE 1.

Number of sample	Rock	Sample site	Formation	K%	K ⁴⁰ 10 ⁻⁵ g/g	Ar ⁴⁰ 10 ⁻⁷ g/g	Ar ⁴⁰ / K ⁴⁰	Age in millions of years		Collector
								Individual	Average	
240	Spherulitic liparite	Kolobenkova Ravine, near Bogopol' Village	Bogopol'	5.08	0.619	0.167	0.0027	48	49	Ye. V. Bykovskaya
7025		Monastyrka River		3.51	0.428	0.120	0.0028	50		A. I. Zhamoyda
441	Tuff lava of quartz porphyry	Vasol'kovo Ravine	Siyanova	3.37	0.411	0.107	0.0026	46	50	N. S. Podgornaya
35		The mouth of the Kalyagina ravine, northeast from Cape Skalistyy		2.62	0.320	0.090	0.0028	50		Ye. V. Bykovskaya
356		Siyanova Ravine, the basin of the Tadushi River		2.33	0.284	0.084	0.0030	53		R. I. Sokolov
4	Dacite	Sadaga River near Vetka Village	-	3.23	0.395	0.144	0.0036	63*		N. S. Podgornaya
165c	Spherulitic porphyry	From a fragment in the tuff, northeast from Lake Topauza		2.28	0.400	0.235	0.0059	103		Ye. V. Bykovskaya
5570	Crystalloclastic tuff of quartz porphyry	Monastyrka River	Monastyrka	3.44	0.420	0.172	0.0041	72	69	Ye. V. Bykovskaya
1756		Rossypnaya Ravine		3.11	0.380	0.153	0.0040	70		N. S. Podgornaya
444	Quartz porphyry	Sadaga River		3.29	0.400	0.153	0.0038	67		N. S. Podgornaya
556		Rotnaya Ravine		2.60	0.317	0.137	0.0043	75		N. S. Podgornaya
606				2.34	0.285	0.115	0.0040	70		N. S. Podgornaya
609	Crystalloclastic tuff of quartz porphyry	Bazovoy Spring, the basin of the Tadusha River	Kisinskaya	2.94	0.360	0.158	0.0044	77	74	R. I. Sokolov
550	Quartz porphyry	Rotnaya Ravine		2.6	0.316	0.137	0.0043	75		N. S. Podgornaya
30a		Cape Skalistyy		1.24	0.151	0.064	0.0043	75		Ye. V. Bykovskaya
155	Porphyry	Headwaters of Sibaygou River	Bazovoy	1.43	0.17	0.082	0.0048	86	79	R. I. Sokolov

* The age was determined without isotope analysis of argon; values obtained are somewhat high.

TABLE 2.

Number of Sample	Rock	Sample site	Geologic age	K%	K ⁴⁰ 10 ⁻⁵ g/g	Ar ⁴⁰ 10 ⁻⁷ g/g	Ar ⁴⁰ K ⁴⁰	Age in millions of years Individual Average	Collector
829a	Granodiorite porphyry	Cape of Four Rocks	Rocks pierce the Bogopol' and Topauza formations	3.05	0.372	0.059	0.0016	31	Ye. V. Bykovskaya
8031a	Granite porphyry (dike)	Cape Balyuzek		3.76	0.459	0.090	0.0020		N. S. Podgornaya
II	Diorite	Vetka Village	Rocks pierce the Vetka granites and the Bogopol' formation	2.04	0.248	0.063	0.0025	44	N. S. Podgornaya
I		Vetka Village		3.34	0.408	0.160	0.0039		
1693		Sadaga River	Rocks pierce the Kisinskaya formation and are overlain by the Monastyrka formation	3.68	0.449	0.187	0.0042	69	N. S. Podgornaya
2247		Cape Mramornyy		3.33	0.406	0.147	0.0036	74	
2099	Granite	Tavayza Mountain		2.94	0.359	0.162	0.0045	64	
870		Vladimir Bay		2.30	0.282	0.115	0.0041	78	
469				2.98	0.364	0.146	0.0040	72	
2048				3.55	0.433	0.158	0.0037	70	
180	Granodiorite	Ol'ga Bay	Rocks pierce deposits with Albian-Cenomanian fauna	2.75	0.335	0.137	0.0041	66	B. L. Lovi
2900				1.93	0.236	0.093	0.0039	72	
536	Granite	Sukhaya River Ravine	Rocks pierce deposits with Albian-Cenomanian fauna	3.12	0.380	0.199	0.0052	69	Ye. A. Radkevich
550	Microgranite	Sudno Mountain		4.10	0.500	0.280	0.0056	91	
149	Diorite (Xenolith in Vladimir granites)	Olga Bay		1.27	0.155	0.083	0.0053	99	
								93	N. S. Podgornaya

Mountains, Cape Mramornyy, Vladimir massif, and others. Earlier intrusions (samples 550, 36, and 149) are represented by hornblende granites, grano-porphyrries and diorites piercing sedimentary rocks of the Albian-Cenomanian age. Later intrusions (samples 2900, 469, 2247, 70, 1693, 1. 2048, and 180. 2099) are made up of granodiorites, and of biotite and leucocratic granites. They metamorphosed acidic extrusives and tuffs of the Kisinskaya formation and their fragments are found in tuffs of the Monastyrka and Siyanova formations in the Ol'ga village area, south of Tadushi Bay, along the Siyanova Ravine, and in other localities.

The Paleogene intrusions include diorites of the Kaban'ya Ravine (sample 11), which pierce Late Cretaceous granites of the Vetka massif (sample 1). The coastal intrusion located south of Cape Briner and others correspond to the early Paleogene volcanic cycle. To the late Paleogene volcanic cycle belong fissure intrusions of granite porphyries (samples 829-a, 1031-a) which pierce tuffaceous-sedimentary rocks of the Topauza formation and partially, granites of the Brusilov formation.

Table 2 presents data of the absolute-age determination of Mesozoic and Cenozoic intrusions.

The experimental data of Tables 1 and 2 attest to the great possibilities of the argon method even for the analysis of recent Cenozoic formations. Some minor deviations probably result from experimental error in determination of short periods of geologic time. Nevertheless, we obtained reliable data on the age of volcanic rocks in the Ol'ga-Tetyukhino area and for Late Cretaceous and Paleogene intrusions. This is seen from the closeness of dates obtained for synchronous rock samples. Table 1 shows average dates for five volcanic formations of the area ranging from 80 to 49 millions of years. Table 2 presents average dates for granitoids from two magmatic complexes of Paleogene and Late Cretaceous age. The geochronologic sequence of volcanic and intrusive rocks, established by the argon method, graphically presented in Figure 3, fully confirms these authors' geologic observations.

We believe that a detailed geochronologic study of individual sections in the areas of abundant volcanic and intrusive sections may be very usefully both for precising data on the length of individual geologic subdivisions and for an objective evaluation of chronologic relationships of the rocks.

Such work is being continued on extrusive rocks older than the Bazovoy formation and younger than the Bogopol' formation.

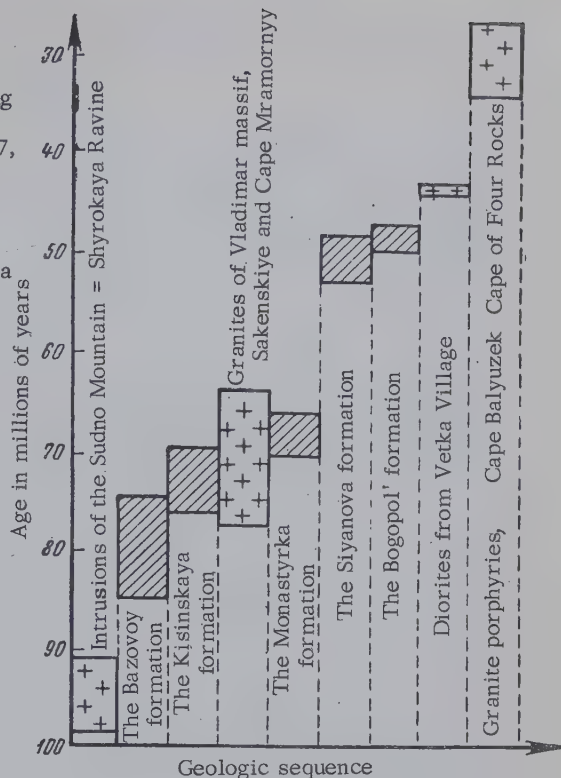


FIGURE 3. Geochronologic sequence of intrusive and extrusive rocks in the Ol'ga-Tetyukhino area according to data obtained by the argon method.

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MAGMATISM OF THE EASTERN SAYAN¹

by

A.I. Suloyev²

REVIEWER'S NOTE

This is really quite a paper. It's difficult to categorize because it's good, but too lengthy. Some of his charts are extremely valuable for geochemical considerations.

ABSTRACT

New geological and petrological data on the range of magmatic complexes and formations of the Eastern Sayan show two primary magmas: basic and granitoid. These magmas were formed through melting of deep-seated layers of the earth crust: basaltic and sialic. During the geosynclinal stage the development of magmas belonging to the Archean, Proterozoic, and Salair [Cambrian] volcanic cycles proceeded consecutively from ultrabasic and basic formations formed in a pre-orogenic or earlier-orogenic geosynclinal development stage to granitoids set up in a synorogenic or later-synorogenic development stage. During the platform stage middle Paleozoic (Lower Devonian) and Mesozoic-Cenozoic cycles of magmatism proceeded directly, without the geosynclinal preparatory stage. Their development, accompanied by faulting, proceeded in reverse order from acidic and alkalic intrusions to predominantly basic eruptives. A further development of deep-seated basic and granitoid magmas was determined first by magmatic differentiation and later by assimilation phenomena which took place during the magma's passage into upper structural layers. The granitoids of geosynclinal magmatic complexes correspond petrochemically to the intermediate types of alk-alkalic rocks of the Pacific Ocean belt. The granitoids and alkalic rocks of the Lower Devonian platform magmatic complex resemble those of the Cenozoic East-Asia alkalic province. The composition of the granitoid magma belonging to the volcanic cycle is conditioned initially chiefly by the sial environment and geosynclinal strata. Magmatic complexes and formations are characterized by definite endogenic mineralizations. Chromium, nickel, cobalt, platinum, diamond, asbestos and other deposits are genetically connected with Proterozoic basic and ultrabasic rocks; gold, muscovite and tin-rare metal pegmatite with upper Proterozoic granitoids. Copper, galenaite and old-ore occurrences are related to the postmagmatic manifestations of Salair granitoids. Deposits of pyrochlore carbonatites, molybdenite, graphite and others belong to Lower Devonian acidic and alkalic granitoids.--Auth. English summ.

* * *

No overall outline of volcanism has yet been developed for Eastern Sayan. Petrographic characteristics of separate intrusions [8-19, 20-24] have been given mainly in published works on this territory, and a description of magmatic rocks of separate complexes or regions has appeared only in a few [1-2, 11-12].

A general outline of volcanism will be given for the first time in this article and new light will be thrown on features of the development of magmatism of this region, based on prospecting data from surveys made in various regions of Eastern Sayan over the last ten years by a large body of VIMS geologists under the author's supervision. Geologic data, both published and unpublished, of the Irkutsk and Buryatsk geological departments of VAGT, VSEGEI of the Academy of Sciences, U. S. S. R., and other geological organizations was utilized in com-

compiling the outline.

BASIC FEATURES OF THE DEVELOPMENT OF MAGMATIC COMPLEXES

Magmatic formations play a very important role in the geological structure of Eastern Sayan, comprising up to 46 percent of its area (see fig. 6). Of these, the more ancient acidic and more alkalic types of granitoids prevail (23 percent), with middle Paleozoic acidic and alkalic granitoids (10 percent); basic and acidic effusives and their tuffs, mainly Cambrian and more rarely Proterozoic, comprise 11 percent; Archean and Proterozoic basic and ultrabasics (2 percent). All these rocks were formed as a result of prolonged, multistage volcanism of various types of deep magma and are related to magmatic complexes³ of different ages and

¹Translated from *Magmatizm vostochnogo Sayana*, *Sovetskaya Geologiya*, No. 6, 1960, p. 3-25.

²Union Institute of Mineral Raw Materials.

³"Magmatic complex" [magmaticheskiy kompleks] in our understanding unites volcanic rocks (extrusive and intrusive) of different age and of different petrochemical composition, and formed from different magmatic chambers, in a single tectono-magmatic cycle of development.

INTERNATIONAL GEOLOGY REVIEW

TABLE 1. Age sequence of magmatic rocks of Eastern Sayan

	Age	Formation	Time of formation relative to main folding	Phase	Rock composition
Magmatic complexes of platform zones	Cenozoic	Basalts	Postorogenic	Quaternary	Subvolcanic facies - basalts, dolerite; crustal - valley basalts, plateau basalts
				Upper Tertiary	Pyroclastic facies - tuffs
	Late Paleozoic - Early Mesozoic	Traps		I	Diorites, diabases, dolerites, porphyrites, gabbro-diabases
	Middle Paleozoic (Lower Devonian)	Acidic and alkalic granitoids		IV	Small intrusions and veined rocks - pegmatites, alkalic microgranites, aplitic granites, granophyres, granite-porphyrries, granosyenite-porphyrries, quartz-porphyrries, orthophyres, felsite-porphyrries, spessarites, diorites, lamprophyres
				III	III Subphase - urtites, ijolites, leucocratic nepheline syenites II Subphase - nepheline and alkalic syenites I Subphase - normal syenites
				II	Granites, subalkalic granites, granosyenites, syenites, granodiorites, quartz monzonites, nordmarkites
				I	Granites, adamellites, granite-rapakivi
	Extrusives of basic, acidic, alkalic composition	I	Quartz, porphyries, felsite-porphyrries, orthophyres, keratophyres, porphyrites		
Ancient magmatic complexes of geosynclinal (mobile) zones	Lower Paleozoic (Salairian)	Granitoids	Late synorogenic	III	Veined series - granite-porphyrries, granodiorite-porphyrries, diorites
				II	Granites, granodiorites, plagiogranites, tonalites
				I	Quartz diorites, diorites, in endocontacts - gabbro, norites, labradorites, hornblendites, pyroxenites
			Basic rocks	Pre-orogenic	I
		Extrusives of basic, acidic, alkalic composition	I		Orthophyres, felsites, albitophyres, keratophyres, quartz porphyries and their tuffs; diabase, pyroxene, and plagioclase - porphyrites and their tuffs
	Upper Sinian	Granitoids	Postorogenic	V	Small intrusions and dikes - granodiorites, quartz diorites, diorites, diabases
	Lower Sinian		Synorogenic	IV	Leucocratic and biotite microcline granites, more rarely granosyenites
				III	Veined series - rare-earth metallic pegmatities, aplites, granites
				II	Granites, granodiorites, more rarely diorites
				I	Granodiorites, tonalites, quartz diorites, diorites

TABLE 1. Age sequence of magmatic rocks of Eastern Sayan (Concluded)

Ancient magmatic complexes of geosynclinal (mobile) zones (concluded)	Age	Formation	Time of formation relative to main folding	Phase	Rock composition
	Lower Sinian (concluded)	Basic and ultrabasic rocks	Early orogenic	I	Gabbro-diorites, gabbro-diabases, gabbro, orthoamphibolites, more rarely peridotites, pyroxenites
		Extrusives of basic, middle, & acidic composition	Preorogenic	I	Quartz porphyries, felsites, porphyrites, porphyroids, metadiabases and their tuffs.
	Lower Proterozoic	Granitoids	Synorogenic	II	Veined series - muscovite pegmatites
				I	Aplitic granites, biotite granites, granodiorites, gneissic quartz-diorites, diorites
		Basic and ultrabasic rocks	Early orogenic	I	Gabbro-diabases, gabbro, dunites, pyroxenites, peridotites, serpentinites, harzburgites, wehr-lites, etc.
		Extrusives of basic, middle, & acidic composition	Pre-orogenic	I	Felsite-porphyries, albitophyres, orthoamphibole shales, diabases, plagioclase, etc. porphyrites
Archean		Granitoids	Synorogenic	III	Veined series - rare-earth pegmatites, granites
				II	Alaskite and biotite granites; more rarely syenites, granodiorites, diorites
				I	Gneiss-granites, gneiss-plagiogranites, gneiss-diorites, granitic injections
		Basic and ultrabasic rocks	Early orogenic	I	Peridotites, pyroxenites, orthoamphibolites, ortho-gneiss-amphibolites, metagabbro

magmatic formations⁴ of geosynclinal, subgeosynclinal and platform structural-facies zones formed with a different intensity over a prolonged period (Archean through Cenozoic). The magmatic development of Eastern Sayan is represented by Table 1.

Ancient Magmatic Complexes of the Geosynclinal Zones (adjustment)

The Archean, lower Proterozoic, upper Proterozoic and lower Paleozoic (Silurian) are distinguished among these complexes.

The Archean magmatic complex has a limited distribution and is related to Archean structures block anticlinoria of Archean deeply metamorphosed gneisses, carbonate rocks, and schists of the Sharyzhelgaysk, Slyndyansk, and Irtyusinsk series). A number of relatively stable folded anticlinorium zones serve as the

basis of the Archean zonal framework. They are relicts of the platform basement, having appeared on the site of the pangeosynclines. Formations either early-orogenic or synorogenic in relation to Archean orogeny were established in the magmatic complex.

Early-orogenic formation of basic and ultrabasic rocks occurred in the early phase of the Archean magmatism in the beginning stage of folding and was represented by small bedded bodies. The great age of these formations was established by the fact that they were contorted into small folds simultaneously with surrounding metamorphic rocks and invaded by dikes of pegmatites genetically associated with Archean granitoids. The formation is complicated by greatly metamorphosed pyroxenites, gabbro and gabbro-diabases, orthoamphibolites partially altered into serpentinites occasionally with gneissic texture, and into metagabbro. They are undifferentiated members of an Archean metamorphic complex conformably related to surrounding gneisses.

"magmatic formation" [magmaticheskiy formatsiya] embraces rocks related in age and petrochemistry, formed from a single magmatic chamber in one or several stages.

Basic rocks of this magmatic formation possibly of paligenic (ultrametamorphic character, occurring as small foci of granitization through partial fusion of their surrounding

beds.

Synorogenic granitoids were formed in three phases. In the first phase, largely biotite, more rarely biotite-hornblende and pyroxene-hornblende gneiss-granites, gneiss-plagiogranites, gneiss-diorites, and migmatites were formed; in the second protoclastic and gneissic alaskite and biotite granites, sometimes (in endocontacts), syenites, granodiorites, and diorites, in the third phase (rocks of the veined series) leucocratic aplitic granites and rare-earth pegmatites.

Rocks of the granitoid formation were formed of gneisses and schists mainly along the axis of the fold zone in the form of elongated massifs and layer-by-layer injection migmatizing the surrounding rocks. Both the surrounding rocks and granitoids took an active part in the tectonic movements, being distorted in the folds. These properties all enable us to consider Archean granitoids as conformable or concordant and to relate them to a type of migmatite-pluton typical of the crystalline basement. Properties of phase I granitoids are: narrow range of alternation, with diffused contacts with surrounding paragneisses; heterogeneous character (zonal separation, dark-minerals enrichment from the more leucocratic); presence in some massifs of pleroplagiogranites related to deposited phenomena of the later diaphthoresis; the wide development of gneissic texture and granoblastic and protoclastic structures; and the prevalence of grayish-green and grayish-pink coloration. Classification of gneiss-granites in phase I is determined by their invasion by alaskite granites. Properties of the inner structure of gneiss-granites leads us to assume that their formation obviously occurred in the main phase of the Archean tectogenesis from magmatic chambers located under the lower bed of gneisses caused by ultrametamorphism during differentiation of granitization.

Alaskite granites of phase II were formed in the concluding stage of folding (late-synorogenic); this is confirmed by the presence in massifs of alaskite granites of sharply expressed intrusive contacts conformable and nonconformable with surrounding gneisses. Characteristic of alaskite gneisses are the following properties: gneissic and massive textures, protoclastic grain structure, sometimes porphyritic, and homogenous character. Moreover, they are distinguished by a large content of microcline and a small content of acidic plagioclase and biotite; by occasional presence in endocontacts of syenites, granodiorites, and diorites, conditioned by assimilation of the surrounding rocks; by a red and pink color and the more alkalic composition than phase I granites. The formation of alaskite granites as well as of phase I granitoids originated from palineogenic alaskite magma arising in deep zone of ultrametamorphism but possibly somewhat pinched off from granitiza-

tization foci in upper horizons. Their Archean age is determined by the fact that they do not invade rocks of the Proterozoic metamorphic complex, and that they were found in detritus of basal conglomerates of the latter, and were invaded by Proterozoic basic and ultrabasic rocks and granitoids.

The veined series of phase III rocks, genetically related to the granitoids, have an insignificant distribution and are distinguished by a uniform composition. Light pink microcline pegmatites prevail. The pegmatite veins, for the most part conformable with Archean structures, are late synorogenic, and the intersecting pegmatites are obviously postorogenic.

The lower Proterozoic complex is manifested slightly in intrageosynclinal fold zones and is represented by preorogenic, early-orogenic, and synorogenic generation.

The pre-orogenic generation of acidic, medium and basic effusives occurred as a result of sporadic volcanic eruptions in submarine conditions during the lower Proterozoic stage of subsidence and of sedimentation of the intrageosyncline. Extrusives, consisting of diabases, plagioclase porphyrites, felsite-porphyrates, albitophytes, quartz porphyries and their tuffs are distributed largely among microcrystalline micaceous schists and more rarely among lower Proterozoic crystalline limestones. They form deposits and bedded bodies subjected, as a consequence of diagenesis, to lower Proterozoic folding and regional metamorphism into amphibolites, and amphibolic and chloritic schist.

The early-orogenic generation of basic and ultrabasic rocks is represented by comparatively small bodies and occasionally by massifs and dikes nonuniformly distributed among narrow belts. The latter are usually extended along the line of deep faults arising at a juncture of lower Proterozoic fold structures and Archean rigid blocks, sometimes being distributed in Salairian structures among Archean horsts.

Intrusions in lower Proterozoic structures are characterized by a concordant emplacement with faulting and cleavage, confirming their dislocated character in common with the surrounding lower Proterozoic rocks. Intrusions localized in Archean structures in most cases have steep and nonconformable contacts with adjacent gneisses, indicative of their postorogenic character relative to Archean folding.

In composition, basic and ultrabasic rocks are represented by complex differentiated abyssal facies: pyroxenite, hornblende and olivine gabbro, gabbro-diabases; hornblendites, peridotites, dunites, pyroxenites, etc. Gradual transitions are noted from ultrabasic rock through gabbro and gabbro-diabases comprising

mainly massifs to the endocontact facies, diorites. Some of these rocks have veins.

In regional metamorphism, because of hydration, basic and ultrabasic rocks are rarely altered to serpentinites, orthoamphibolites, amphibolites, talc, and other schists. Basic and ultrabasic rocks are probably differentiation products of deep gabbro magma. These rocks are related to the lower Proterozoic on the basis that they intersect metamorphic and eruptive rocks of the Archean, the lower Proterozoic and effusive formations, and themselves are invaded and metamorphosed by lower and upper Proterozoic granitoid intrusions and enter into the composition of the detritus of Sinian basal conglomerates of the Baikal.

The synorogenic formation of granitoids is characterized by small intrusive formations arising in the lower Proterozoic phase of folding. Granitoids have local distribution in lower Proterozoic and Archean metamorphic beds. Gray biotite granites, granodiorites, plagiogranites, diorites, and in endocontacts, aplite-like granites are all separated from the granitoids. All these are characterized by a gneissic texture and protoclastic structure. In the second phase were intruded rocks of veined granitoids (muscovite pegmatites, genetically related to granitoid formation and widely developed in Archean gneisses and crystalline shales of the Biryusinsk series). The lower Proterozoic age of the granitoid formation is based on its intersection with Archean and lower Proterozoic rocks and invasion by upper Proterozoic granitoids.

The upper Proterozoic (Sinian) complex (the most widely distributed) includes the early and late Sinian magmatic series, originating at separate times in intrageosynclinal zones. The early Sinian series is complicated by various effusive and intrusive rocks, among which the following are established.

The pre-orogenic generation of extrusives of basic, intermediate, and, more rarely, of acidic composition are represented largely by diabases, porphyrites, felsite-porphyrtes, quartz-porphyrtes, and other rocks erupted in submarine conditions in the lower Sinian stage of subsidence of the intrageosyncline sedimentation. These rocks form small bedded bodies and, occasionally, large deposits comprising separate suites. The extrusives are contorted in folds together with their surrounding upper Proterozoic phyllite schists and sandstones and are considerably altered by regional metamorphism.

The early-orogenic generation of basic and ultrabasic rocks obviously occurred prior to the main phase of folding, arising along deep faults along the borders of Archean horsts and Proterozoic folding. These rocks form small

massifs, stocks and dikes, elongated in the form of fractured belts.

The formation is represented by various rocks: gneissic gabbro, gabbro-diabases, gabbro-diorites, hornblendites, occasionally, peridotites and pyroxenites. These rocks underwent deformation together with their surrounding upper Proterozoic beds, they being partially transformed into orthoamphibolites with relicts of ophitic structure, serpentinites and green chloritic schists.

This generation of basic and ultrabasic rocks is a product of deep basic-gabbro-magma differentiation, contaminated to a marked degree in the upward migration. This is confirmed by the increased content of alkali (potassium), phosphorus, and fluorine and the presence of a variety of more acidic rocks (monzonites and diorites).

The early-synorogenic age of these rocks is determined on the basis that they breach Archean and Proterozoic formations and are intersected by granites and pegmatites of early Sinian age.

The synorogenic granitoids were formed from a multiple-phase intrusive process. In the first phase, small intrusions were formed of biotitic and biotite-hornblende granodiorites and plagiogranites which gradually underwent marginal alteration into quartz diorites, diorites, and tonalites as a result of hybridization.

The formation of large batholithic massifs and numerous laminar injections of biotite-muscovite, and partly tourmalinized granites occurred in the second phase. These granites usually form structurally complex massifs, in the endocontacts of which granodiorites, granosyenites, and more rarely, diorites are distributed, as well as porphyritic and coarse-grained granite varieties resulting from assimilation.

Rocks of the veined series, aplite granites, granodiorites, granite-porphyrtes, aplites, rare-metal pegmatites, porphyrites, and lamprophyres, genetically related with micaceous granites were intruded in the third phase. Most widely distributed are aplites and rare-metal pegmatites (Sayan regional belt), related to the anticline and interbedding lower Proterozoic microcrystalline micaceous schists and amphibolites.

The formation of small massifs of leucocratic, and biotite microcline granites and partially of granosyenites is associated with the fourth phase. The granitoids parallel the general direction of the two-stage Proterozoic structures and, as a rule, are related to the Proterozoic anticlinal core and Archean block

uplifts separated by zones of deep faults. Thus, we may relate the formation of granitoids to a type of synorogenic batholith formed in the intra-geosynclinal fold zones under conditions of isochronous kinematics of granitoids and of the surrounding Proterozoic rocks.

The characteristic properties of early Sinian granites are its irregular grain structure; its massive, sometimes gneissic, texture; hypidiomorphic granular, often blastogranitic, sometimes porphyritic, structure; as well as the presence of implicational, micrographic, and myrmecitic mineral intergrowth, predominantly gray in color, and the presence of a high-temperature contact aureole.

Rare-metal pegmatites usually characteristically concordant with the structures and are early-synorogenic; only an insignificant part of the intersecting pegmatites are obviously related to varieties of early Sinian rocks.

The late Sinian series of magmatic rocks is poorly developed in eastern Sayan. It had been formed in the post-orogenic stage of late Sinian tectogenesis in the form of small intrusions and dikes (phase V), being differentiates of parent granitoid magma of the early Sinian series. These intrusions are represented by diorites, quartz diorites, granodiorites, and diabases. Judging by the morphology and the gravitation of these rocks to the area of batholithic granitoids, one may obviously consider them as genetically related hypabyssal intrusions.

The placement of small intrusions is controlled by faulting. They lie among Archean and Proterozoic formations, their age being established on the rather conventional basis that some of these rocks penetrate subgeosynclinal upper Sinian deposits of the Baikal complex.

The lower Paleozoic (Salairian) complex of subgeosynclinal fold zones consists of three formations.

The pre-orogenic generation of extrusives resulted from widespread eruptions of basic lava (diabase, pyroxene, and plagioclase porphyrites, spilites, diabases, andesites, and their tuffs) distributed in the lower and upper parts of the crust, as well as acidic and alkaline types (quartz porphyries, felsites, albitophyres, orthophyres, and their tuffs) in the middle parts. Eruption occurred along major faults in the southwestern Kizhi-Khem-Kazry region of the bend, in the beginning stage of development of the subgeosyncline in submarine conditions, and in the Agul-Udin intramontane bend in the form of areal crustal facies.

The predominance among volcanic formations of basic varieties indicates that the for-

mation of extrusives resulted from products of flaking of the basalt magma. During Salairian orogeny and metamorphism, these extrusives, together with the subordinate interbedding of siliceous shales and limestones, were subjected to strong folding and alteration to ophiolites. The age of formation of effusives developed in eastern Sayan and Tuva is defined as Salairian (above the Lower Cambrian-Lenian stage) on the basis of findings of archeocyate in the limestone interbeds.

It is also possible that younger effusives (Lower Devonian) may appear in the Agul-Udin bend.

The pre-orogenic formation of basic rocks (gabbro, gabbro-diabases, diabases, and diabase porphyries) is represented by small stocks and dikes mainly deposited among Salairian extrusives, and sometimes Precambrian beds. Their close petrographic and spatial relations to the extrusives indicate that the major intrusions are the volcanic roots of the Salairian extrusives.

Late-synorogenic granitoids are widespread as batholiths and stock-like bodies spatially related mainly to Salairian and somewhat to Precambrian fold structures. Rocks of this formation are oriented northwest-southeast usually conformable with surrounding rocks.

These features permit us to relate granitoids to the late synorogenic, i.e., to those intruding the late stage of the Salairian folding with marked control by faults. The granitoids, originating in three phases, vary in composition. The first main phase saw the formation of biotitic and biotite-hornblende quartz diorites, diorites, and occasionally as related granites and basic rocks (pyroxene and olivine gabbro, norites, hornblendites, pyroxenites, labrodorites), affected by assimilation; in the second: biotitic and biotite-hornblende granites, granodiorites, tonalites, and plagiogranites; in the third: rocks of veined series (diorites, granodiorites, porphyrites, granite-porphyries).

The granitoids are characterized by: abnormally high content of dark components causing their melanocratic appearance; predominance of hornblende; minor potassic feldspar content, rather basic plagioclase; with increased alumina content, as well as a glomeroblastic and spotty distribution of minerals, enrichment by xenoliths of the surrounding rocks, structure ranging from granitic to gabbroitic or trachytoid, and presence of features of hybridization (irregular association of minerals, the poikilitic structures, and anomalous chemical composition).

The age boundary of the granitoids is determined by the fact that they cut Lower Cambrian

intrusive and sedimentary formations and are penetrated by Lower Devonian acidic and alkaline granitoids. Moreover, on the basis of similarity of the Eastern-Sayan granitoids with the Muolsk granitoids of Tuva, for which an absolute age of 443-448 million years has been determined, their age also must be considered Cambrian.

Magmatic Complexes of the Platform Zones

The development of magmatic complexes (Middle Paleozoic, upper Paleozoic-early Mesozoic and Cenozoic) is genetically related to tectonic activation of ancient rigid platform regions of the eastern Sayan, which had completely lost features of their geosynclinal development by the end of the Sinian in the north-east and at the end of the Cambrian in the south-east. These magmatic complexes originated in connection with Precambrian and lower Paleozoic structural-facies platform zones.

Middle Paleozoic Magmatic Complex: Volcanism This cycle arose from deep chambers, was caused by tectonic movements in the region's post-orogenic stage and is represented by the following formations.

Post-orogenic extrusives appeared in the region of Salairian fold zone. The volcanics are deposited in the form of bedded deposits among Lower Devonian (shales, sandstones, and conglomerates) in narrow grabens separated by faulting from the Salairian structures. They consist of olivine and basalt porphyries in the lower part and by felsites and quartz porphyries in the upper. The extrusives, formed under continental conditions synchronously with their surrounding red beds, are products of magmatic differentiation of deep basalt. These rocks are dated on the basis of their transgression on Salairian granitoids, their presence in conglomerates of lower Devonian sedimentary-extrusive beds, and Salairian granitoid detritus.

The post-orogenic acidic and alkaline granites are widespread in the form of small batholiths or massifs, and pipes in the Salairian and Precambrian zones mainly near deep faults or at their intersection or confluence.

This is a multi-phase formation. In the first phase were formed biotite porphyritic granites and adamellites, altered at the endocontacts into rapakivi, monzonites and granodiorites; in the second phase: leucocratic granites and granosyenites, as well as subalkalic granites and syenites; in the third phase: normal pyroxene syenites (first subphase), then alkaline rocks, nepheline pyroxene and riebeckite syenites (second subphase), and (in

the third subphase) leucocratic nepheline syenites and ultra-alkalic rocks (ijolites and urtites with quartz syenites and granosyenites in the endocontacts). The fourth phase saw the formation of minor intrusions and rocks of the veined series - riebeckite microgranites, granodiorite-porphyries, aplitic granites, granite-porphyries, granosyenite-porphyries, quartz porphyries, felsite-porphyries, orthophyres, spessarites, lamprophyres and pegmatites.

The formation of middle Paleozoic granitoids is characterized by a complex structure, discordant contacts, and disorientation with relation to surrounding structures. These granitoids, hypabyssal post-orogenic typical plutons of faults, are characteristic for platform formations related to Precambrian and lower Paleozoic orogeny, without geosynclinal forerunners.

The Lower Devonian age of the granitoids is based on their penetration of Lower Devonian sedimentary-volcanic formations, and the presence of their detritus in the basal conglomerates of the Middle Devonian. Data on the determination of the absolute age of similar granites from the Brensk massif (270-280 million years according to V. Ye. Kudryavtsev) confirm the Lower Devonian age of middle Paleozoic acidic and alkaline granitoids.

The lower Paleozoic-early Mesozoic magmatic complex of small hypabyssal intrusions and dikes of traprock is represented by a formation of basic and intermediate rocks poorly developed along fracture zones where Precambrian structures meet with Cambrian deposits of the Siberian Shield.

Pyroxene, hornblende and olivine gabbro-diabases, and occasionally dolerites, diabases and diorites are distinguished in the traprocks, being end products of deep basalt magma differentiation. By usual methods, their age is determined as Permian-Triassic.

The Cenozoic magmatic complex is genetically related to the development of an unusual Cenozoic neotectogenesis (arcogenesis [arching? - "arkogenez"] according to Ye. V. Pavlovsky). It is represented by crustal basalts, sometimes pyroclastic and subvolcanic facies, related to Precambrian and, to a lesser degree, by Salairian tectonic structures. Aerial pyroclastic tuffs of the Upper Tertiary (Miocene) are related to volcanoes located along reactivated fault zones on limited areas of the plateau. The most widespread crustal facies of continental basalts and their subvolcanic counterpart - sills, necks and dikes (conduits) - were formed in the Quaternary, first as plateau-basalts, then (middle Quaternary) as copious eruptions of valley basalts.

In composition, the basalts are essentially

olivine with massive, amygdoidal, porous, and scoriaceous texture. By nature of eruptions and internal structure the basalts belong to the shield type, intermediate between strictly central and fissured types.

COMPARATIVE GEOLOGIC-PETROGRAPHIC CHARACTERISTICS OF GRANITOIDS OF MAGMATIC COMPLEXES OF DIFFERENT AGE

Of all the Eastern Sayan magmatic formations described, it is the granitoids of magmatic complexes of different age that are of greatest metallogenic interest. Their major characteristics are shown in Table 2, which also shows that granitoids differ mainly in content of dark components. In the Archean complex granitoids the basic femic minerals are biotite, more rarely hornblende and pyroxene. In the Proterozoic complex granitoids, biotite, muscovite, often hornblende and sometimes tourmaline are developed. Characteristic of Salairian granites are hornblende and biotite; in the hybrid varieties, pyroxene and olivine. In the middle Paleozoic granitoids the more usual femic minerals are biotite, riebeckite, and pyroxene (agerite or diopside-hedenbergite).

Some differences were found in quantitative ratios of different feldspars. In Archean granitoids (phase I), plagioclase prevails over calcium-rich feldspar [kalishpat], in alaskite granites (phase II) calcium-rich feldspar prevails over normal plagioclase. In Proterozoic and Salairian granitoids, normal plagioclase prevails over calcium-rich feldspar. The middle Paleozoic is distinguished from more ancient granitoids by a higher content of alkaline aluminosilicates - calcium-rich feldspar and nepheline, with an insignificant presence of plagioclase.

Valuable information can be gained by comparing the accessory mineral content of various granitoids. The most common for all granitoids of complexes of different age are zircon, apatite, sphene, some ilmenite, rutile and pyrite, and sometimes hematite. Orthite magnetite, monazite, and occasionally garnet, aeschynite and tourmaline also occur in Archean and Proterozoic granitoids. In Salairian and middle Paleozoic granitoids these minerals are not always insignificant. The fact that middle Paleozoic granitoids contain such mixtures as molybdenite, fluorite, pyrochlore, polycrase, euxenite, fergusonite, priorite, and even graphite may distinguish them from ancient granitoids.

Furthermore, in all granitoids, both ancient and young, the content of the same element-mixtures (titanium, phosphorus, strontium, barium) is established at 0.1 percent. In Proterozoic granitoids manganese, cobalt, zinc and lithium are also present in such amounts; in the Salairian: manganese, nickel, chromium,

zinc; in the middle Paleozoic: manganese, zinc, sometimes lithium and cesium. Elements present in amounts of 0.01 percent and less may also differ. Archean alaskite granites (phase II) have manganese, nickel, vanadium, zirconium, niobium, copper and zinc in common with phase I granitoids, but are distinguished from them by traces of gallium, yttrium, ytterbium and silver. In Proterozoic granitoids, besides those noted, lanthanum, cerium, beryllium, scandium and tin are present. In Salairian and middle Paleozoic granitoids also appear niobium, indium, tungsten, molybdenum and bismuth. Precambrian granitoids differ in structural features. Characteristic of Archean and Proterozoic granitoids are the gneissic texture and granoblastic and pteroclastic structure; Salairian and middle Paleozoic granitoids, mainly the massive textures and hypidiomorphic-granular, and often porphyritic structures. Coloring also differs. Pink and meat-red shades prevail in Archean alaskitic granitoids (phase II) and middle Paleozoic granitoids; grayish-greenish, dark-gray and gray shades in Archean (phase I), Proterozoic, and Salairian granitoids. The character of post-magmatic ore manifestations, the composition of facies of endocontacts and veined series, and the dimensions of massifs of granitoids and their areal distribution are also different (table 2).

PETROCHEMICAL PROPERTIES OF GRANITOIDS OF MAGMATIC COMPLEXES OF DIFFERENT AGE

Together with the geological-petrochemical data, the differing ages of granitoids are confirmed also by the variety in chemical composition of granitoids of different magmatic complexes, as expressed in vector diagrams (figs. 1 - 4) compiled by the Zavaritsky method.

Comparison of chemical compositions of Archean granitoids with Daly's averages (fig. 1) shows that Archean granitoids are acidic magmas of the calc-alkalic series, varying in composition from alaskitic leucocratic granites (phase II), supersaturated with alumina, rich in alkalis and poor in femic components, to normal and plagioclase gneiss-granites (phase I).

Proterozoic granitoids are rocks of acid magma of the calc-alkali series and are somewhat more basic and less alkalic than Archean granitoids. The plottings of vectors of Proterozoic granitoids (fig. 2) coincide with those for the calc-alkali granite associations of Daly. Analyses of Salairian granitoids (fig. 3) showed a continuous petrochemical calc-alkali series with enrichment or increase in alumina content ranging from acid granitoids through rocks of intermediate (diorite) composition with increase of silicic acid and decrease of alkali for basic varieties. The general plotting of a vector for Salairian granitoids is displaced considerably farther left than that for typical calc-

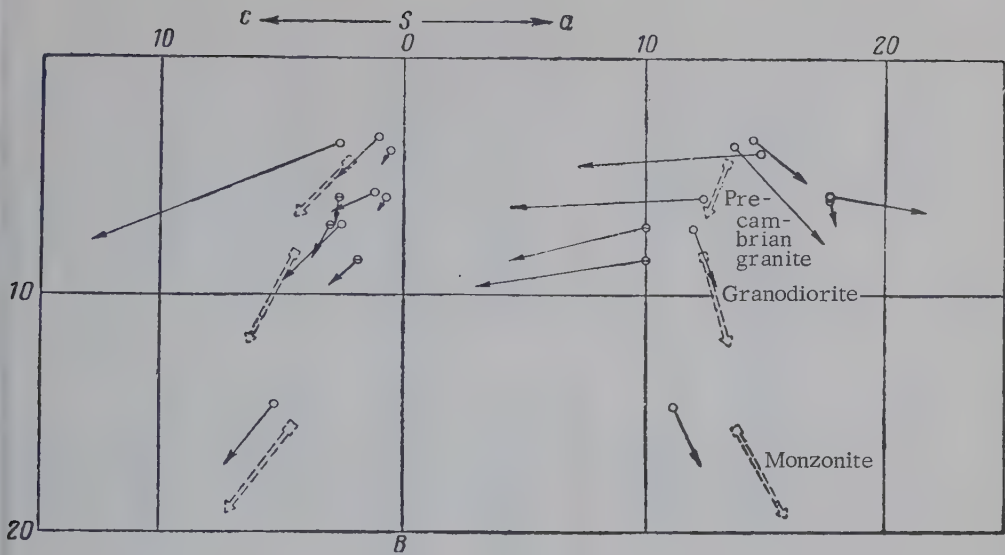


FIGURE 1. Chemical composition of Archean granitoids

○→ - gneiss-granites, migmatites (phase I) ○→ - alaskite granites (phase II)
 [---] - intrusive rocks of intermediate composition, according to Daly

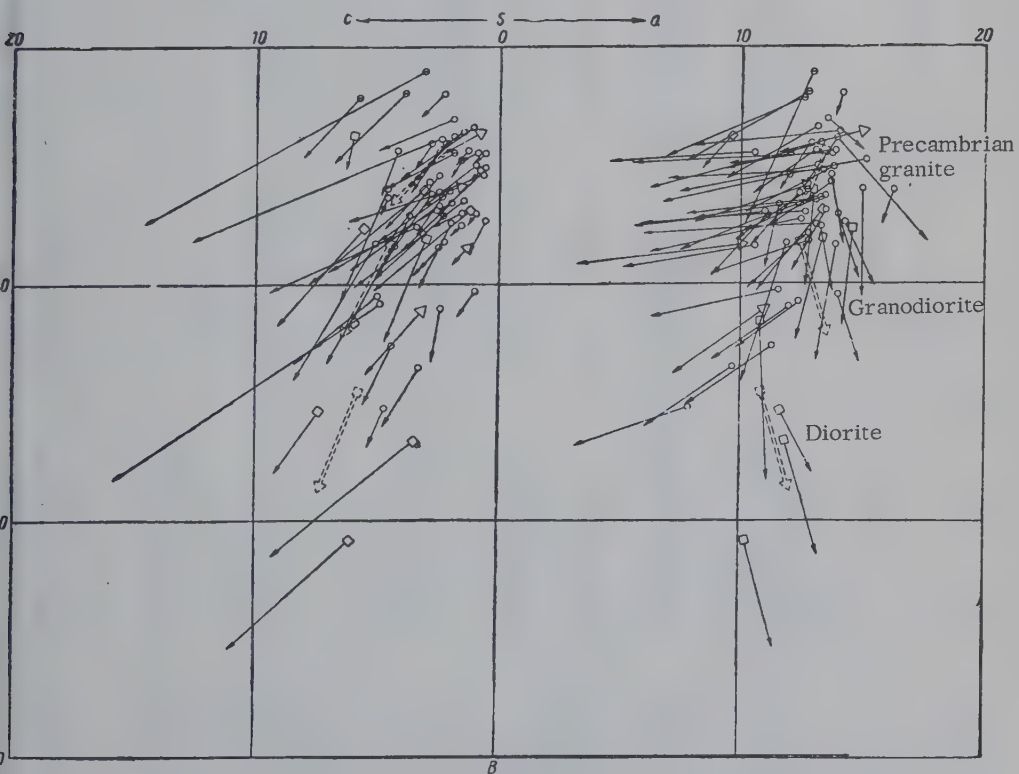


FIGURE 2. Chemical composition of Proterozoic granitoids

--- diorites, granodiorites, trondhjemites (phase I) ○→ - granites, plagiogranites (phase II);
 [---] - pegmatites (phase III) △→ - leucocratic microcline granites (phase IV);
 [---] - intrusive rocks of intermediate composition, according to Daly

TABLE 11. Comparative characteristics of the geologic-petrographic properties of granitoids of the Eastern Sayan magmatic complexes of different age

Geologic-petrographic features and properties	Magmatic complex	Archean		Lower Proterozoic	Upper Proterozoic	Salairian (Lower Paleozoic)
		Phase I	Phase II			
Facies and petrographic types		Gneiss-Granites, gneiss-pleroplogranites, gneiss-diorites	Alaskite granites	Granites, granodiorites, plagiogranites	Granites, granodiorites, plagiogranites	Granites, granodiorites, plagiogranites, monzonites, tonalites, quartz diorites, diorites
		Grains of unequal size	Grains of unequal size, porphyritic	Grains of unequal size, porphyritic	Grains of unequal size, porphyritic	Grains of unequal size
		Gneissic, spotted striated	Massive, gneissic	Massive, gneissic	Massive, gneissic	Massive
Physical and External structure	Macrostructure	Gray-greenish, gray-pink, light gray	Pink, brownish red	Gray, grayish-pink	Gray, light gray	Greenish-gray, dark-gray
Microstructural		Granoblastic, blastoclastic, xenomorphic-granular, blastoporphyrific	Granoblastic, protoclastic, blastoporphyrific, xenomorphic-granular	Granoblastic, protoclastic, aplitic, xenomorphic-granular, hypidiomorphic-granular, porphyritic	Xenomorphic-granular, hypidiomorphic-granular, blastogranitic	Hypidiomorphic-granular, trachitic, gabbro-like
		More plagioclase No. 20 than calcium-rich feldspar	More calcium-rich feldspar than plagioclase No. 20	More plagioclase Nos. 40-50 than calcium-rich feldspar	More plagioclase No. 20 than calcium-rich feldspar	More plagioclase Nos. 35-45 than calcium-rich feldspar
Mineralogical	Dark minerals	Biotite, hornblende, pyroxene	Biotite	Biotite, hornblende	Biotite, muscovite, hornblende	Biotite, hornblende, pyroxene, olivine
	Accessory minerals	Apatite, zircon, sphene, orthite, garnet, magnetite, ilmenite, rutile, pyrite	Apatite, orthite, zircon, sphene, magnetite, ilmenite, aeschynite	Apatite, zircon, sphene, orthite, hematite, rutile, garnet, magnetite, ilmenite	Apatite zircon, orthite, tourmaline, garnet, rutile, sphene, rare earth mineral, pyrite, magnetite, ilmenite	Zircon, apatite, sphene, magnetite, orthite, garnet, rutile, pyrite, ilmenite

Geochemical	Elements-mixtures	Mn, Ni, Co, Ti, V, Zr, Cu, Pb, Ga, Sn, P, Sr, Ba	Mn, Ni, Ti, V, Zr, Pb, Ag, Ga, Y, Yb, Nb, P, Sr, Ba	Mn, Ni, Co, Ti, V, Zr, Cu, Pb, Zn, Ga, La, Y, Yb, Sr, Ba, Ce	Mn, Ni, Co, Ti, V, Zr, Cu, Pb, Zn, Sn, La, Ga, Be, Sc, Y, Yb, P, Sr, Li, Ba, Ce	Mn, Ni, Co, Ti, V, Cr, Mo, Zr, Nb, Cu, Pb, Ag, Bi, Zn, Sn, Ga, In, Be, Sc, La, Y, Yb, P, Sr, Li, Ba
	Facies of endocontacts		Syenites, granosyenites, granodiorites	Aplitic granites, quartz diorites	Granosyenites, tonalites, trondhjemites, quartz diorites, diorites	Gabbro-norites, gabbro, hornblendites, pyroxenites
Geologic	Rocks of veined series		Pegmatites, aplites, aplitic granites	Pegmatites, aplites, trondhjemites	Pegmatites, aplites, aplitic granites, granite-porphyrries, granodiorite-porphyrries, diorites, porphyries, lamprophyres	Aplites, granite porphyries, quartz-porphyrries, granodiorite-porphyrries, porphyries, microdiorites, tonalites
	Distribution in percent of area	3 percent	1 percent	Tens of percent	13 percent	6 percent
Area of massifs		15-50, 100, 300, 800 km ²	15-50, 200 km ²	Up to 1-3, 20 to 60 km ²	Small injections 25-100, 100-300, 500, 2,000 km ²	25-100, 300, 800, 3,000 km ²
Postmagmatic mineralization			Rare earths	Muscovite	Tin, beryllium, lithium, niobium, tantalum, rare earths, gold, and sulfides (pyrite, arsenopyrite)	Copper, lead, zinc, gold

Note: Underlining designates principal features.

TABLE II. Comparative characteristics of the geologic-petrographic properties of granitoids of the Eastern Sayan magmatic complexes of different age (Concluded)

Magmatic complex		Middle Paleozoic (Lower Devonian)			
Geologic-petrographic features and properties	Facies and petrographic types	Phase I	Phase II	Phase III	Phase IV
		Granites, adamellites, granite-rapakivi	Leucocratic granites subalkalic granites, granosyenites, syenites	Syenites, alkaline syenites, nepheline syenites, ijolites	Alkalic granites, granite-porphyrates, granophyres, aplitic granites
Physical and External structure	Macrostructure	Medium-large-grained, porphyritic	Grains of unequal size, porphyritic	Grains of unequal size	Fine-grained (aphanitic) coarse-grained porphyritic
	Texture	Massive	Massive	Massive, gneissic, brecciated	Massive
	Color	Grayish-pink, red	Bright-gray, red, pink	Red, pink, cinnamon	Grayish-white
Microstructural		Granitic, hypidiomorphic-granular, porphyritic	Granitic, hypidiomorphic-granular, porphyritic, taxitic	Hypidiomorphic-granular, xenomorphic-granular	Pan-xenomorphic-granular, hypidiomorphic-granular, porphyritic
Mineralogical	Feldspars and number of plagioclase	More calcium-rich feldspar than plagioclase No. 20	More microcline-perthite than plagioclase No. 20	More microcline-perthite than albite-oligoclase	More microcline than plagioclase No. 20
	Dark minerals	Biotite, hornblende	Biotite, hornblende pyroxene, muscovite	Pyroxene (aegirite), riebeckite, biotite	Biotite, riebeckite
	Accessory minerals	Apatite, sphene, zircon, orthite, molybdenite, fluorite, magnetite	Apatite, zircon, sphene, orthite, fluorite, garnet, cassiterite, magnetite, ilmenite, molybdenite, hematite, pyrochlore, euxenite, fergusonite	Apatite, zircon, sphene, fluorite, magnetite, ilmenite, fergusonite, pyrochlore, priorite, graphite	Apatite, sphene, zircon, fluorite, magnetite, ilmenite

Geochemical	Elements - mixtures	Mn, Ni, Co, Ti, V, Cr, W, <u>Zr</u> , Cu, Pb, <u>Ag</u> , <u>Zn</u> , Ga, Be, Y, Yb, <u>Li</u> , <u>Sr</u> , <u>Ba</u>	Mn, Ni, Co, Ti, V, Cr, Mo, W, Zr, Hf, Nb, Cu, Pb, Ag, Bi, <u>Zn</u> , Ga, Sn, Ge, Be, Sc, Ce, La, Y, Yb, P, Li, <u>Sr</u> , <u>Ba</u>	Mn, Ni, Co, Ti, V, Cr, Mo, <u>Zr</u> , Nb, Cu, Pb, Sn, Ga, La, Yb, Y, Ce	Mn, Ni, Co, Ti, V, Mo, <u>Zr</u> , Cu, Pb, <u>Ag</u> , <u>Zn</u> , Sn, Ga, Be, Y, Yb, <u>Li</u> , <u>Sr</u> , <u>Ba</u>
Geologic	Facies of endocontacts	Fine-grained granite	Granodiorites, quartz monzonites, nordmarkites, diorites	Quartz syenites, granosyenites	Granodiorites
	Rocks of veined series	<u>Pegmatites, aplites</u>	Pegmatites, aplites, quartz porphyries, felsite-porphyrries, orthophyres, granites, granosyenite-porphyrries, lamprophyres	—	—
	Distribution in percent of area	Tens of percent	9 percent	Tens of percent	Tens of percent
Area of massifs		To 1-2 km ²	25-100, 300, 600 1, 000 km ²	8-60 km ²	To 1-3 km ²
Postmagmatic mineralization		Molybdenum, piezoquartz	Niobium, zirconium, rare earths (yttrium), molybdenum	Niobium, tantalum, graphite	Molybdenum, polymetals, arsenic

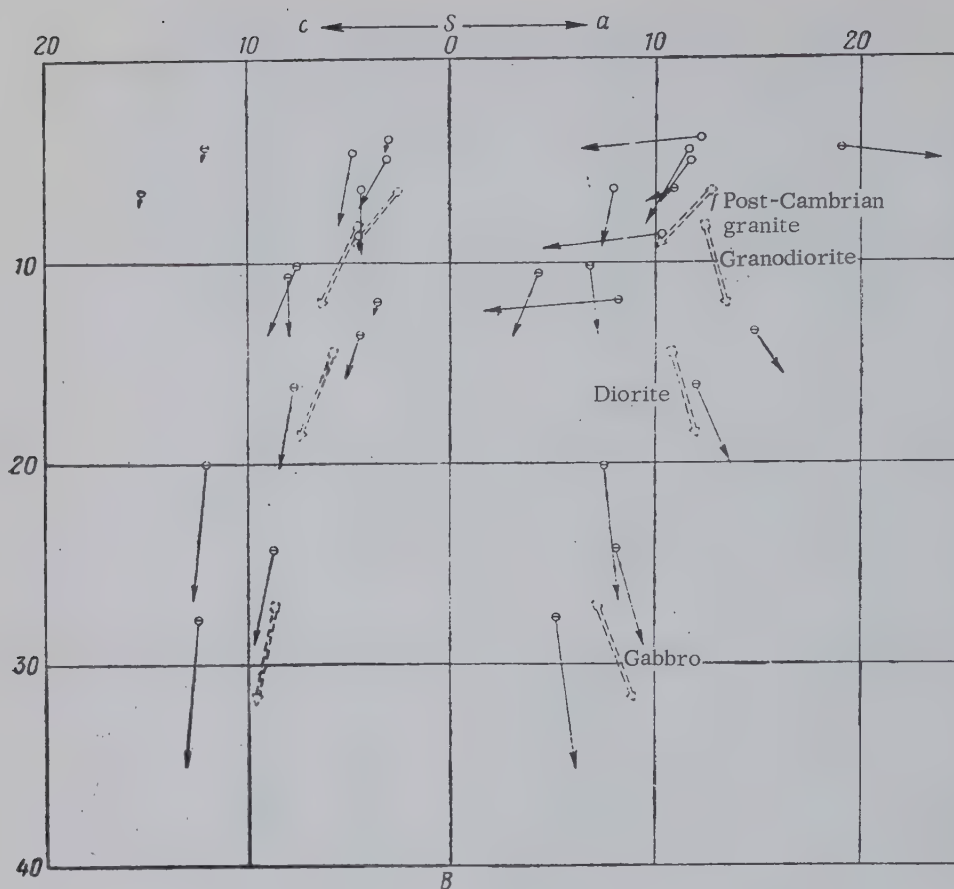


FIGURE 3. Chemical composition of lower Paleozoic granitoids

- - gabbro, gabbro-norites, diorites (phase I)
- - granodiorites, plagiogranites, tonalites (phase II)
- - intrusive rocks of intermediate composition, according to Daly

alkali associations; on this basis we consider these rocks, as a whole, as a magma of intermediate composition.

Petrochemical data on middle Paleozoic granitoids are very important. The vector diagram of these rocks (fig. 4) shows that middle Paleozoic granitoids have a wide range (from acidic-subalkalic to alkalic and sometimes to basic alkalic varieties). Characteristic of the latter chemical series are granitoids supersaturated by alkalis and calcium, as distinguished from granites and granosyenites of the main phase supersaturated by aluminum. Characteristic of granitoids of this complex are the high ratios of iron to magnesium and an almost complete absence of magnesium in nepheline rocks; this is one of the criteria of their formation in platform conditions.

The composite variation diagram (fig. 5)

clearly shows the distribution of granitoid complexes of various ages. The Archean series is represented by a short variation line located in the diagram's upper part and sloping up to the right. It is between the lines corresponding to the average calc-alkali association and the rock series of the East Asia alkali province (according to Zavoritsky); this indicates the alaskitic subalkalic character of Archean Eastern Sayan granitoids. The variation curve for Proterozoic granitoids is positioned in the upper part of the diagram and coincides on projection ASB with the variation line of the average calc-alkali association and veers left only in its upper portion, in conformance with the pegmatite composition. The curve of the Proterozoic granitoids on projection CSB is intermediate between curves for the calc-alkali average and the East Asia alkalic series.

In the upper part of the diagram the curve

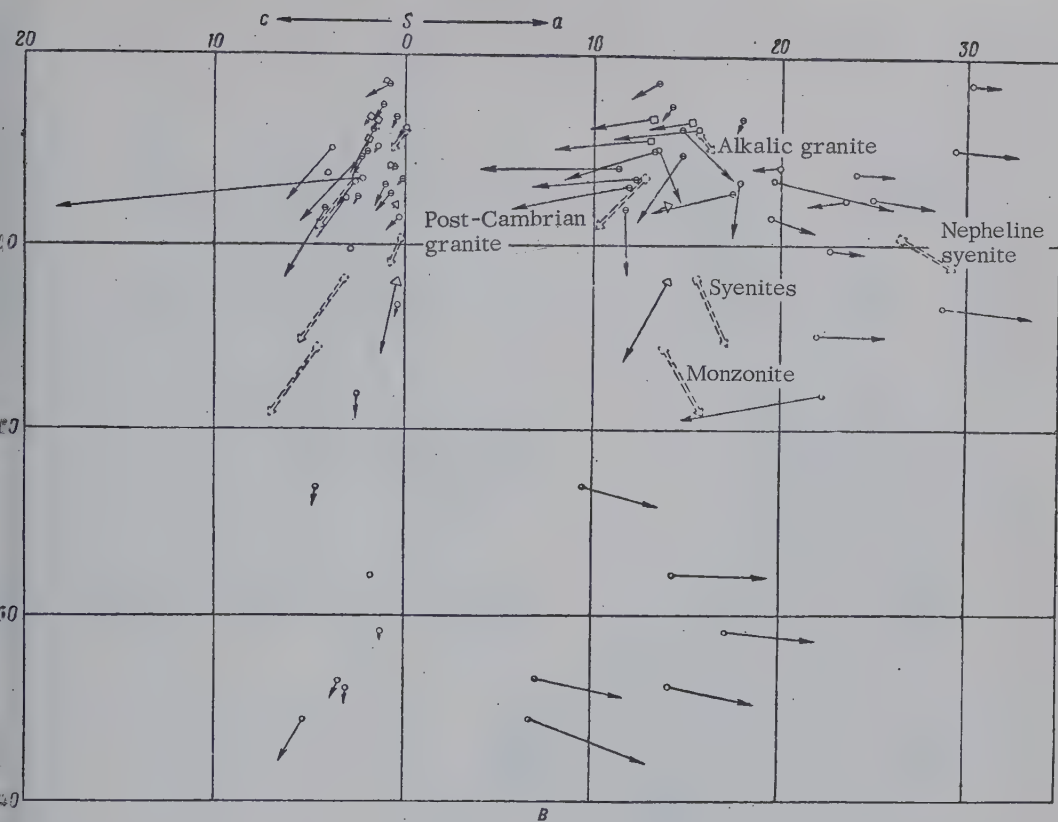


FIGURE 4. Chemical composition of middle Paleozoic acidic and alkalic granitoids

- → - granites, granite-rapakivi (phase I)
- — - leucocratic granites, granosyenites (phase II)
- | - syenites, nepheline syenites, ijolites (phase III)
- / - felsites
- - - - - intrusive rocks of intermediate composition according to Daly

departs to the left, intersecting the calc-alkali average. Proterozoic granitoids (also upper part of diagram) also branch steeply downward from its apex in conformance with the composition of phase IV leucocratic microcline granites. The line of Salairian granitoids on projections ASB and CSB is considerably left of and parallel to the curve for the calc-alkali average. As a whole, the marked prevalence of rocks of intermediate magma of the calc-alkali series is characteristic. The variation curve of middle Paleozoic granitoids is midway between the calc-alkali average and the East Asia series, in general repeating the latter's contour; this indicates the subalkalic character of middle Paleozoic rocks. In the lower part of the diagram this curve departs to the right, intersecting the average line for East Asia in conformance with the composition of ijolites. In the upper

part of the diagram the series of middle Proterozoic rocks branches right of the East Asia curve and, like the latter, turning steeply to the left in its upper portion, encircling a broad field of subalkalic and alkalic rocks.

The alkalic character of middle Paleozoic granitoids is very apparent on area CSB where the curve of these rocks is considerably to the right of the East Asia alkalic province line.

The regularity of variation curves for granitoids underlines the fixed trend in time in the generation and development of deep granitoid calc-alkali magma ranging from the alaskite granite magma in the Archean, through normal granite in the Proterozoic to diorite in the Salairian. Granitoids of the ancient geosynclinal magmatic complexes of eastern Sayan

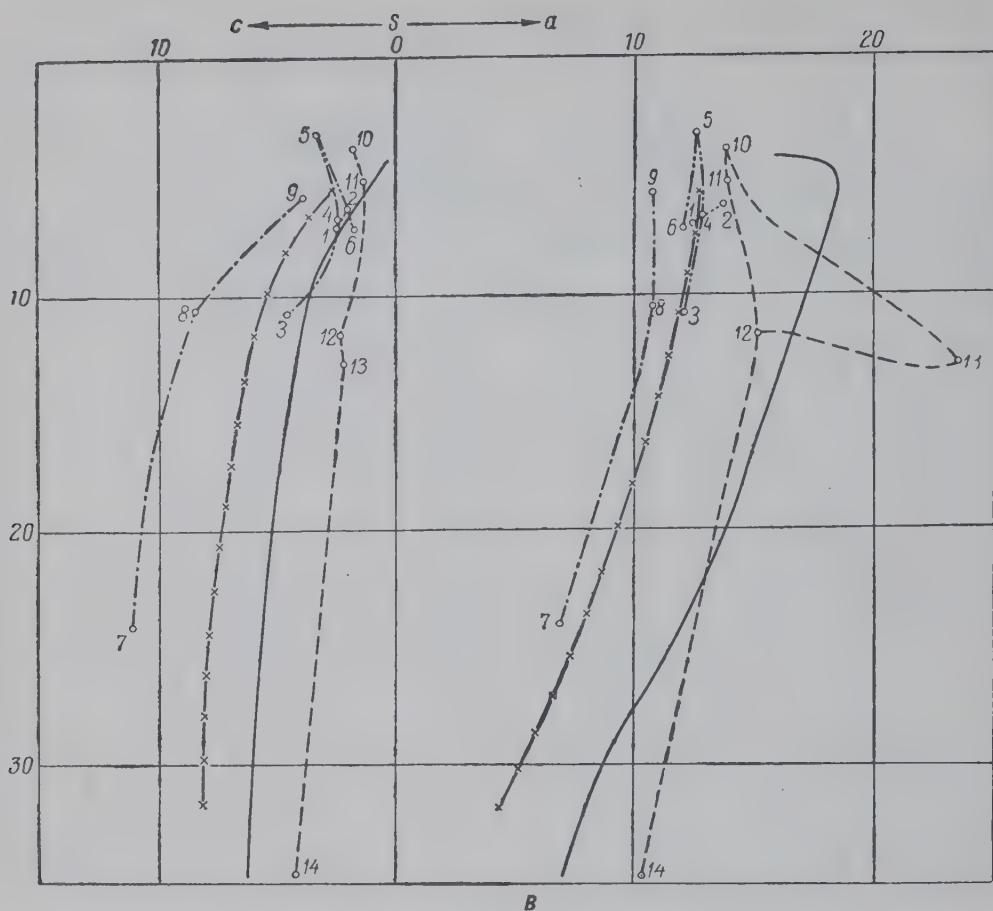


FIGURE 5. Composite variation petrographic diagram of Eastern Sayan magmatic complexes of different age

Variation lines of granitoids

- · — · — Archean
- — — Proterozoic
- · — · — lower Paleozoic
- — — middle Paleozoic
- · — · — calc-alkalic associations (Intermediate type), after A.N. Zavaritsky
- — — Eastern Asiatic alkalic province after Zavaritsky
- o — mean values

generally correspond to average calc-alkali types of the Pacific Ocean belt. Granitoids and alkalic rocks of the middle Paleozoic platform complex are petrochemically very similar to the Cenozoic rocks of the East Asia alkalic province.

SOME REGULARITIES OF LOCATION OF MAGMATIC COMPLEXES

Magmatic complexes of the same age in various structural-facies zones of Eastern Sayan are characterized by a definite regularity of location (see fig. 6). Lower and upper Proterozoic extrusive deposits related to submarine

eruptions are distributed in corresponding intra-geosynclinal zones mainly among terrigenous deposits in the form of bedded deposits or lenses. Lower Cambrian extrusives, formed under submarine and terrestrial conditions, are related to: first, subgeosynclinal Kizhi-Khem-Kazyr Salairian zones; second, Udin-Agul intermontane depressions, as surface deposits covering the whole structure.

Lower Devonian and Cenozoic extrusives, appearing under continental conditions, are located in activated platforms of mainly Precambrian and sometimes Salairian age, in zones of downwarping and faulting of diverse directions.

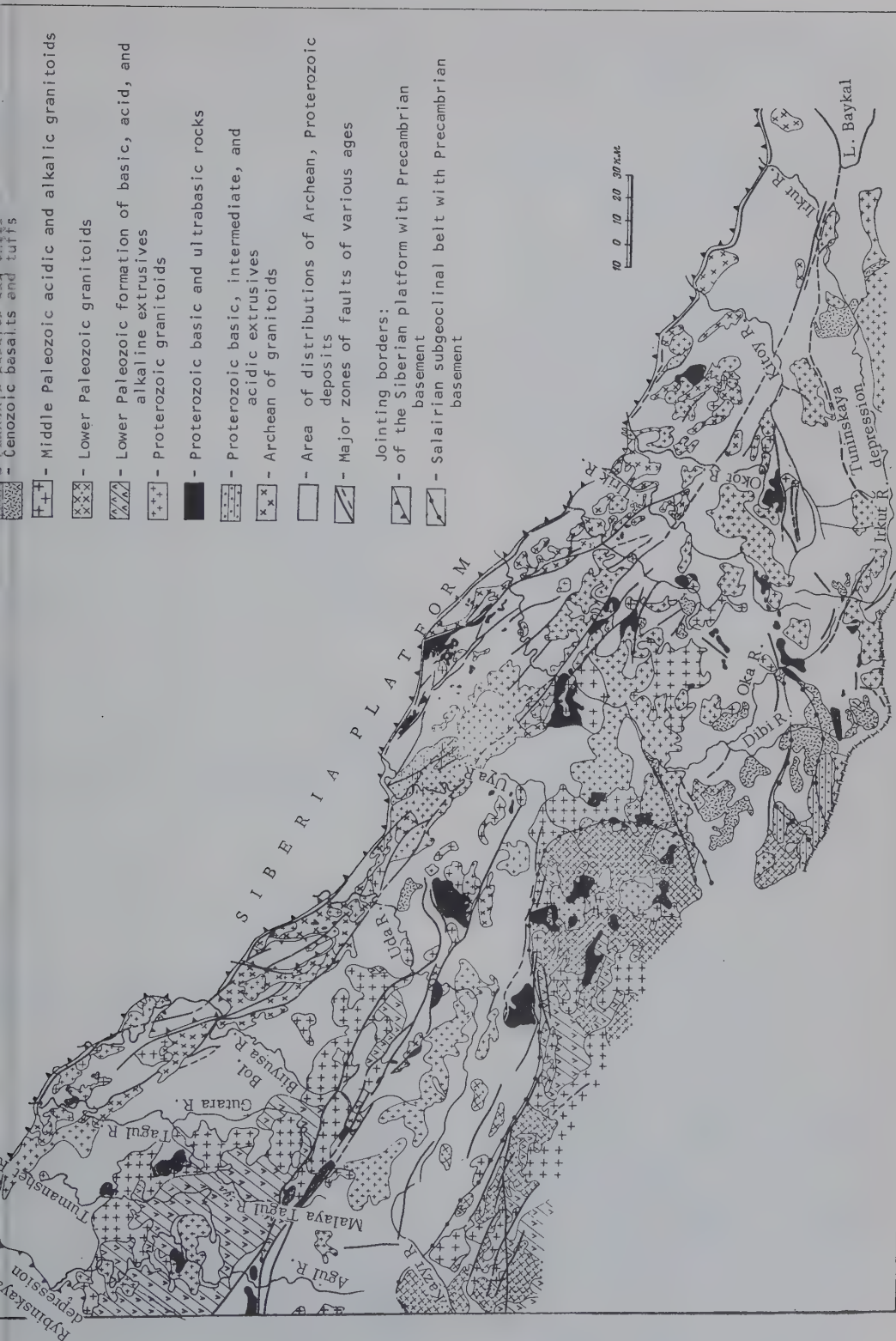


FIGURE 6. Distribution of magmatic rocks of Eastern Sayan.

Formations of basic and ultrabasic intrusive rocks of the Lower and Upper Proterozoic magmatic complexes are distributed, as a rule, in zones of deep fractures on detritus of Proterozoic and Archean structures, mainly among Proterozoic and, more rarely, Archean strata. Their areal distribution is subject to topography, forming discontinuous belts: Udin-Agul, Ospin, Bokson-Urik and Sayan regions conformable with Precambrian folds and faults.

Archean magmatic complex granitoids form lengthened massifs among Archean fold structures largely in anticlinal stages. Proterozoic batholithic granitoid massifs are distributed mainly in cores of anticlinal folds of corresponding age, and in Archean structures often near fracture zones which separate them from the Proterozoic. Salairian granitoids are related largely to lower Paleozoic structure-facies zones, sometimes to Precambrian structures, near their juncture. Their distribution within structural-facies zones is thus proven to be often controlled by fracture zones. Granitoids of the middle Paleozoic magmatic complex are located widely along crush faults in the Kizhi-Khem-Kazyr Salairian zone and in the Udin-Agul downwarp where they form a series of intrusions extended along these structures. Within Precambrian structural-facies zones the massifs of these granitoids are located also near regional faults demarcating structural stages or strata of different age. The areal distribution of granitoids of different age is also subordinated by a somewhat rare regular formation of parallel belts conforming to overall structure in a northwest - southeast direction. The northeast belt, mainly Archean granitoids, is located in the northeast part of Eastern Sayan within the gneisses of the Sharyzhelgaysk series comprising the Archean Kitoy-Onot-Burukhtuysk anticlinal zone at its juncture with Lower Cambrian platform deposits of the Siberian Shield.

To the southwest, within the Archean (Slyudyanka and Biryusinsk) and Proterozoic strata of the Sayan area, a wide belt of Proterozoic and some Archean granitoids extend along the regional longitudinal deep faults. Farther to the southwest, in the central portion, in the region of the Udin-Agul downwarping is a belt involving largely middle Paleozoic acid and alkalic granitoids. Southwest of this belt, along the axis of the main Eastern Sayan anticlinorium extends a belt mainly of Proterozoic granitoids and isolated massifs of middle Paleozoic granitoids. This belt, consisting of Salairian and middle Paleozoic granitoids, extends into the southwest portion of Eastern Sayan, in the region of the Kizhi-Khem-Kazyr Salairian structure.

THE QUESTION OF ORIGIN OF EASTERN SAYAN MAGMATIC ROCKS

In processes of formation and development

of magmatism in geosynclinal (mobile) zones and stable platform regions of the Eastern Sayan we notice definite properties and regularities formulated in the following:

1. In the light of new geologic and petrologic data, it may be stated that all magmatic varieties appearing during development of Eastern Sayan geosynclinal zones are determined by the generation of two parent magmas periodically arising in the crust: of basic magma by local fusion of gabbro-basalt shell in the deepest parts and of the granitoid magma by fusion of sialic (granite) layer in shallower chambers. This viewpoint is in agreement with that of most researchers and is in complete agreement with the hypotheses of geologists and seismologists on the existence in the crust of three solid shells: the upper granite; the intermediate gabbro-basaltic; and the lower peridotite.

2. Together with the generation in the Proterozoic and lower Paleozoic of parent magma in the solid deep shells of the crust, the Archean geosynclinal zone of Eastern Sayan is also characterized by: formation of palingenic magma in chambers underneath the lower strata of gneisses. This is due to the partial fusion of geosynclinal substrate during granitization by deeper emanations (D. S. Korzhinsky's transmagmatization solutions).

3. The magmatic formations developed with the Eastern Sayan geosynclinal zones appear to be syndromic: from ultrabasic and basic formations at the early stages of geosynclinal development, to acidic-granitoidic — being intruded in the synorogenic stage of their development.

4. Between the formation of magmatic formations (extrusives and intrusive) of basic magma and the formation of the granitoid magma faulting took place through changes in the crust.

5. The example of Eastern Sayan establishes that the basic magma was intruded from the main magma chamber in the final stage of geosynclinal development, during the period of deep faulting.

6. The formation of granitoids of the geosynclinal zones in each ancient volcanic cycle originated from parent granitoid calc-alkalic magma. The magma composition at the time of its generation was affected by the fusion of the substrate of the sialic shell or the geosynclinal strata and by the various geotectonic environments through which the magma arose. For example, in the Archean cycle the formation of palingenic alaskite magma is associated with the granitization by deep magmas of the solid substrate of the Archean geosynclinal stratum. A parent calc-alkalic magma of granodiorite composition, closely related to the fusion of sialic layers similar in compo-

tion, was generated in the Proterozoic.

Lower Paleozoic granitoids, characterized by petrochemical similarity to acidic and basic magma, may be explained by the synchronous fusion of sialic and gabbro-basalt layers in the transition zones and formation of an intermediate "hybrid" diorite magma.

7. Development of basic and granitoid magmas arising in deep magmatic chambers was further determined first by differentiation, and then by assimilation and contamination as the magma moved into the upper structural stages.

8. These magmatic rocks, extrusives, ultrabasic intrusions → basic intrusions, changing in sequence and closely interrelated, arose in geosynclinal zones in almost every ancient cycle in the process of differentiation of parent gabbro-basalt magma.

9. The differentiation of Proterozoic and lower Paleozoic granitoid parent magma led first to more basic differentiates (diorites or monodiorites), and then the more acidic (normal and leucocratic). In the final phases of magmatism there arose small intrusions and dikes of granodiorite and diorite composition, obviously related to deeper, still active zones in the magmatic chamber.

10. Assimilation and contamination features of ancient magmatic complexes of the East Sayan geosynclinal zones are best expressed in earlier more basic granitoid types. The formation of the latter is closely related to the maximum folding of the solid substrate of movement zones causing favorable conditions for development of assimilation processes in the upper structural stages.

Later formations (leucocratic and alaskite granites) show minor assimilation features; this is explained by the migration of their functions in the upper horizons in the late-synorogenic stage, when the dying-out of fold movements made it unfavorable for assimilation phenomena.

11. The generation of primary granitoids and basic (basaltic) magmas and their further development originated mainly on the pattern of magma development in a geosynclinal zone. The basic difference is only that the magmatization processes in the platform stage took place without the downwarping but with the accompanying faulting.

12. In the platform stage of development, in contrast to that of geosynclinal zones, the appearance of magmatic formations occurred hydrothermally [?]: from more acid and alkaline intrusions of earlier platform stages to basic, largely extrusive formations being included in the final stages of development.

13. The origin of middle Paleozoic platform granitoids of acid and alkalic composition is related to granosyenite magma arising in the magmatic chamber through fusion of the sial layer of similar composition with deeper alkalic emanations.

14. With the further development of primary granitoid magma of granosyenite composition, formation of rocks during differentiation and assimilation occurred in the following sequence: granites, adamellite granites, granosyenites → normal syenites, basic and nepheline syenites, ijolites, urtites → leucocratic granites. It was thus established that features of assimilation are better expressed in the more alkalic series of rocks (alkalic syenites, nepheline syenites, ijolites, urtites), formed in the final stages of granosyenite magma development after the main phase intrusion of granites and granosyenites under the influence of alkaline solutions and of the assimilation of carbonate in the upper structural stages.

RELATION OF MINERALIZATION TO INTRUSIONS

The endogenic mineralization of Eastern Sayan, related to distinct structural-metallogenic belts, zones, pockets and fissures, is associated with intrusive rocks of various magmatic formations and complexes (see table 2).

Ore shows distributed in gneiss strata related to Archean alaskite granites are represented presently only by rare-earth pegmatites and minor pneumatohydrothermal deposits of phlogopite. Magmatic deposits and ore shows of chrome, nickel, cobalt, platinoids, diamonds, etc., and hydrothermal metasomatic ores — asbestos, talc, magnesite and nephrite — are genetically related to lower and upper Proterozoic basic and ultrabasic rocks.

Muscovite pegmatites, related to the productive stratum of Archean gneisses and crystalline shales of the Biryusinsk series are considered veined differentiates mainly of lower Proterozoic calc-alkalic granitoids.

The tin-rare earth mineralization, represented by the pegmatites with cassiterite, spodumene, beryllium and tantalum niobates, appear widely within the lower Proterozoic amphibolite-micaceous-schist suite, in the pegmatite belt associated with upper Proterozoic granitoids (phase II). Hydrothermal formations with a variety of rare-earth mineralizations (lanthanum, cerium, yttrium) are associated with leucocratic and biotite microcline granites (phase IV) of upper Proterozoic granitoids. Ore shows of molybdenite, represented by pegmatites and quartz-carbonate formations, are to all appearances associated with this same granite phase.

Hydrothermal deposits and ore shows of gold-quartz veins, often with sulphide (pyrite-arsenopyrite) mineralization, are localized in Proterozoic pyritized phyllitic schists, carbonate rocks and altered granites. They are probably genetically related to small Late Sinian post-batholith hypabyssal intrusions and dikes of granodiorites and diorites (phase V). Minerals related to the Salairian subgeosynclinal fold zone and genetically related to the lower Paleozoic magmatic complex (granitoids and their veined facies: granite-porphyrries), are represented by ore shows of copper (chalcopyrite), galenite, sphalerite and gold. Endogenic mineralization of various types genetically related to middle Paleozoic acidic and alkalic platform magmas are highly important.

Hydrothermal ore shows of pegmatite and piezoquartz of this stage are related to biotite granites of phase I.

Deposits of metasomatic albites and vein formations with mineralization of yttrium, niobium, and zirconium are related to post-magmatic activity of leucocratic granites, granosyenites and syenites (phase II) of the middle Paleozoic.

Metasomatic deposits of niobium-pyroxenite carbonatites as well as graphite are genetically related to alkalic and nepheline syenites (phase III), and finally, hydrothermal ore manifestations of molybdenite, polymetals, and native arsenic to small intrusions and dikes of the subalkalic aplitic granites (phase IV). Nepheline syenites of the Botogolsk massif, also related to this complex, are important as raw material for aluminum production.

Thus, the most important endogenic metallogeny in East Sayan to date is that of the Proterozoic and middle Paleozoic tectonic-magmatic complexes. We may consider these areas most promising for new mineral deposits.

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RADIO-WAVE METHOD OF GEOLOGICAL MAPPING¹

by

A.D. Frolov²

ABSTRACT

Practical methods of using radio waves in geological mapping are considered. The history and basic principles of the method are briefly outlined. When transmitted radio waves penetrate the earth to a definite depth, they induce currents in the heterogeneous geological structures encountered (ore veins, contacts of different rocks, ground-water lenses, for example). The electromagnetic fields of these currents superimposed on the primary radio signal cause local anomalies qualitatively and quantitatively depending on the nature of the heterogeneity and the interrelations between the electromagnetic parameters (ϵ, ρ, μ) and the surrounding medium.

The results of field measurements by the radio-wave method of geological mapping in different regions are described. The author's work and experiments of other investigators indicate the feasibility of radio-wave methods for large-scale geological mapping and exploration. The portable measuring apparatus, PINP-1, is a high-selective microvoltmeter measuring 3-10 mv in the [frequency] range of 150,000-450,000 s. p. s. [cycles per second?], which is assembled according to the superheterodyne circuit made entirely of transistors. It is equipped with a special repeated magnetic antenna (it measures magnetic components and polarization elements of radiopole), needle-type volt-indicator, and a loud-speaker for sound monitoring. It is small enough and light enough to be strapped to the operator's chest during operation. --M. Russell.

* * *

It is known that radio waves, transmitted by high-power stations, are broadcast over much of the earth's crust. The possibility of using radio-wave fields in geological investigations has long ago interested the geophysicists of various countries. The radio-wave field, in passing along the earth's crust, changes the magnitude of the voltage and its structure in accordance with the electrical properties of the upper parts of the crust because the energy of the field penetrating into the earth is changed into the energy of conduction currents, the intensity of which depends on the conductivity of the rocks.

As early as 1934 E. Cloos [11] demonstrated the possibility of the influence of geological heterogeneity on the magnitude of voltage of the field of the radio station. He reported on the first experiments for detecting heterogeneity in the geological structure of the crust for various intensities of audibility of the radio station, using a receiving set placed in an automobile. In 1936 E. Spiecker [16] and in 1937 V. P. Pekhoroshev outlined a geophysical method of surveying based on this principle. More comprehensive experiments on an explanation of the influence of geological structures on

radio reception were conducted in 1942 by B. F. Howell [12]. He observed excellent reproduction of an anomalous picture with measurements on various days and also showed that the experimental conductors (tubes, leads, etc.) and rugged terrain interfered with attempts to detect anomalies caused by geological structure. In 1946 L. Kerwin [13] conducted experiments on the registration of anomalies of the radio-wave field which were due to the geological structure. He used a direction finder (probably of naval design) which was set up in a special wooden car towed by an automobile. Vertically framed rotating antennae were used to measure the horizontal radio field, which was made up of magnetic components and the magnitude of which was recorded automatically. However, L. Kerwin showed that for practical application in geological cartography of the radio-wave field further refinements were necessary.

In subsequent years, advances in radio electronics and the theory of electromagnetic fields, has contributed toward improvement in this technique.³ From theories of distribution of radio waves along the earth's surface, we know that the greater the distance from the broadcasting radio station and the less the

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²M. V. Lomonosov State Institute of Moscow.

³We are not concerned here with the potentiality of using radio waves for studies in mines, tunnels, caves, involving depths of several dozens of meters, although under certain conditions this is possible [14, 15].

electrical conductivity of the upper layers of earth, the deeper and greater is the penetration of energy of the radio waves into the earth. In addition, we can state that in the "remote zone" from the broadcasting radio station (at distances of more than ten times the length of the emitting waves) the field of the radio station is spread in the form of flat electromagnetic waves. Dispersion of the flat, vertical polarized waves along the earth-air boundary is characterized by relatively simple principles. We established (theoretically and experimentally) that here the vector of energy U_{mov} - Poynting \vec{P} and electrical vector consisting of the field \vec{E} are inclined at a certain angle (fig. 1, b), which reflect consumption of part of the electromagnetic energy in the ground, the final conductor [3, 17]. Thus in the case of the spread of radio waves along the earth's surface (fig. 1, b) there will always be vertical (E_z) and horizontal (E_p) components of the electrical components of the radio field alternating in space. The vector of the magnetic component (\vec{H}) remains horizontal, and therefore, under rocks of the same kind, there will be present only the horizontal magnetic component (H_p), which is directed along a line connecting the radio station and the observation point. The vertical magnetic component (H_z) must be absent.

As a result of studies made by V.A. Fok [7] we established that anomalies in radio-wave transmission along the earth's surface was defined mainly by electric properties of the "take-off" (region near the transmitting antenna) and "landing" (region near the receiving antenna) of the wave sites. In our case the "take-off site (transmitting station) remains unchanged and determines mainly the normal field, but the "landing" site changes all the time and defines an anomalous field caused by the presence of geological inhomogeneities near the receiving

antenna; this is confirmed in practice [5, 9]. In an electromagnetic field geological inhomogeneities of any kind may be in the form of eddy circuit currents of corresponding shape and position. With considerable dimensions of the inhomogeneities, both in extent and in depth, they may, in a majority of cases with satisfactory practical accuracy, be presented in the form of linear currents coursing in the upper parts of these inhomogeneities [4, 9]. As a result of superposition of fields of these currents on the primary radio field there arise anomalies of voltage and polarization of the electric and magnetic components of the field of the radio station; these also are the subject of research in measurements in geophysical prospecting. These anomalies may be more clearly fixed in measurement of the radio-wave magnetic components since, in this case, the vertical magnetic component (H_z) appears, giving the so-called "pure anomaly" effect [5], and the available horizontal component (H_p) changes its value and direction within the anomalous zone. This circumstance is a basic one in choosing the magnetic (and not electric) component for measurement of the radio wave in geologic prospecting. Another important factor is the convenience of measuring under field conditions elements of the field using the frame or magnetic antennae [4, 8, 9]. It was also possible to measure with this angle of inclination of the whole vector \vec{H} (so-called angle α) according to the angle of deviation of the floor of the frame from the horizontal position with a minimum of reception (vector \vec{H} was located on the floor of the frame); these measurements are usually used in work done by the induction method. All three values named above are bound by the ratio $\tan \alpha \approx \frac{H_z}{H_p}$. Of practical interest also is the study of the phase relationship in measurements of the field of the radio station (as well

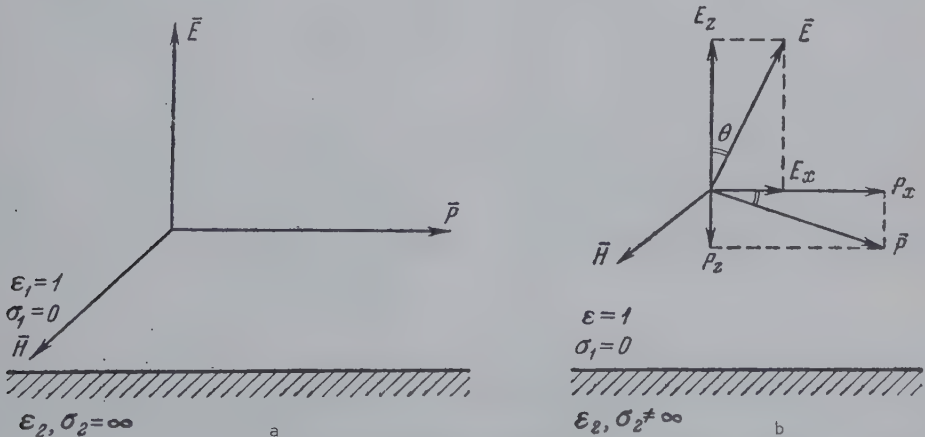


FIGURE 1. Vectoral diagrams of plate electromagnetic waves at point of contact of medium-air

a - medium of perfect conductivity; b - medium of imperfect conductivity (earth)

as in the induction method), which will possibly contribute toward essential advancement in deciding the potential and sensitivity of the method. However, this point has not yet been adequately worked out.

It follows from all that has been said above that in the use of the field of the radio station for cartography of geological heterogeneities it is first necessary to establish the work conditions selected for measurement of the broadcasting radio station, checking the routine of the work schedule and constancy of hearing it in a given district,⁴ and later measuring selected parts of the anomalous field to discover its geological structure. Figure 2 presents characteristic anomalies rising over different geological heterogeneities. These anomalies appear as the primary criteria in a geological interpretation of the exposed disturbances of the radio field. The described method, being in

essence an unusual variety of the induction method, differs advantageously from the latter (and from other high-frequency methods of electric geological surveying) by extraordinarily high productivity, simplicity of manufacture, and interpretation of field measurements; at the same time there is no need for a special field generator, and the measuring apparatus can also form and use a very small-sized and highly sensitive field.

As a result of the experimental investigations conducted in the Soviet Union in 1946-1948 by a group from the All-Union Scientific Research Institute of Geophysical Prospecting under the directorship of A.G. Tarkhov, certain basic techniques for field work were developed, and a field measuring instrument of the "Ruda" type was constructed. A.G. Tarkhov presented a new method of prospecting: the "radiokip"⁵ method

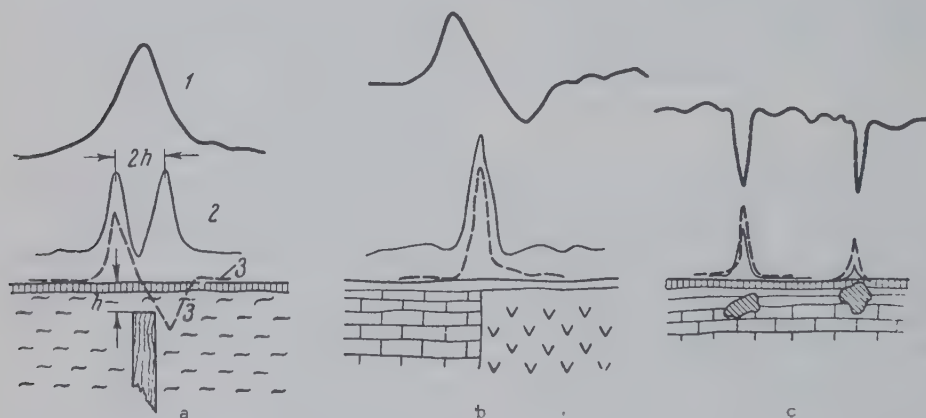


FIGURE 2. Typical anomalies for radio-wave fields for basic types of geologic inhomogeneities

a - narrow localized zone of amplified electroconductivity (ore vein, lens, zone of crushing, fault displacements, etc)

b - interface

c - local bodies with amplified electroconductivity: karst cavities, argillaceous accumulations, etc.

1 - horizontal magnetic component

2 - vertical magnetic component

3 - slope of polar vector of magnetic components

⁴Where there are striking variations in the field of the radio station during the day it is necessary to use a second apparatus to perform the special measurements and to interpret the results (as in magnetic surveying).

⁵"Radiokip", the name introduced by us for the method, did not seem to be exact in view of the fact that the comparison method with field measurements of the radio field for geological prospecting purposes usually is not used because comparative measurements of the field are almost never needed for measurements by comparison means, and the applied instruments are not radio comparers. Therefore, in the future we will call the described method the radio-wave method of geological cartography, which more clearly expresses its nature.

(radio comparison and direction) intended primarily for ore prospecting.

Later on this method with the use of the "Ruda" instrument was tested in various regions of the U. S. S. R. in the prospecting of beds of vein-impregnated ores of colored and rare metals, and clear results were rarely obtained. Here it must be noted that in most cases this method was attempted when even all the other geophysical methods had not given sharp results; in other cases it was applied without a clear-cut idea about the sound technique of measurement and in the absence of the necessary apparatus [2]. Absence of definitive results caused the method to be deemed unacceptable, and its more extensive check in practice was rejected.

In 1954 in collaboration with V. K. Khmelevskoy we applied the radio-wave method widely (as apart of other geophysical methods), not for ore prospecting but for mapping contacts of dissimilar rocks and karst, disintegrated zones [9]. Sufficient material was obtained as a result of our experiments on the northern Ural to verify the definite applicability of this method for mapping of contacts of dissimilar rocks (limestones, clay shales, sandstones, porphyrites, etc.), the zones of structural disturbances (especially irrigated sections); and parts with interstitial and karst cavities. We made further experiments in the Far East (1957) and in other regions (1959) which substantiated these findings. Our especially-erected, repeat observations on the same profiles gave proof that the anomalous representation of the field was almost unchanged: curves H_z and H_p , received as a result of measurements taken on different days and even in different years, agreed in form very exactly. This refutes the opinion about poor reproducibility of radio-wave measurements and the impossibility of correlation of observations conducted on different days. However, differences in magnitude of the voltage of the radio station field, received with measurements at different times, were noted. This is to be expected because the voltage of the radio station field, which was measured, depended on varied conditions of propagation of the radio waves under different hydrometeorological conditions. Errors in the measurements due to the variable calibrations (magnification) of the instruments also had to be taken into account and especially of the IP-12M, where the guaranteed accuracy of the calibrations is on the order of ± 25 percent [9].

The constancy of the anomalous representations of the field made possible geological interpretation of field measurements both on individual profiles and profile maps as well as on isoline maps with a scale of $i = \arctan \frac{H_z}{H_p}$.

This requires only an approximately accurate and stable working instrument for measurements of the same magnitude of error in comparable measurements of horizontal and vertical components of the voltage of the radio field from point to point.

In the conduction of surface surveys and the plotting of isoline maps it was necessary to use a technique similar to that of detailed magnetic prospecting works; measurements were performed at the beginning and end of the day's work for the same point which was constant for a given section (zero point); a variation in the field was measured after certain intervals of time (20 or 40 minutes), and the desired measurements in the reverse direction after 10 or 15 points, etc.

In the taking of measurements for individual profiles or a system of profiles, when the purpose was not the plotting of an isoline map, all of the special steps indicated above were dropped and (if there were no marked time variations in the field) only measurements of the radio station field along the profile were used. Then graphs were constructed for the corresponding values of H_p , H_z , α . On the basis of the theoretical and experimentally determined ratios in anomalous zones a geological interpretation was qualitatively rendered on the various heterogeneities -- contact of dissimilar rocks, a good conducting zone, sunken formations, etc. [4, 9].

Figures 3, 4, and 5 present some of the results of our experiments conducted in recent years. As can be seen from the graphs of the vertical (H_z) and horizontal (H_p) components of the radio-wave field and the schematic geological profiles, in all cases the contacts of dissimilar rocks and other heterogeneities were sharply fixed by characteristic anomalies (fig. 2) of the radio field (maximum of H_z and inflexion of H_p , a maximum or minimum of angle α). Figure 6 presents a map of a profile measurement by the method of radio-wave geological mapping with localization of mineralized zones of disintegration (according to the data of M. A. Gutov, Trans-Baikal expedition). H_z and angle α were measured. The zones of disintegration were quite sharply traced by anomalies of the radio field (minimum of H_z and inflexion of angle α), regardless of the fact that the apparatus used was not sensitive enough.

These examples testify to the broad possibilities of the radio-wave method in mapping contacts between the most varied lithologic varieties of rocks, zones of structural disturbances, and so forth. In addition, this method can be used to fix contacts of rocks which differ not only in electrical conduction but also in magnetic and dielectrical penetration, which imparts to radio-wave geological

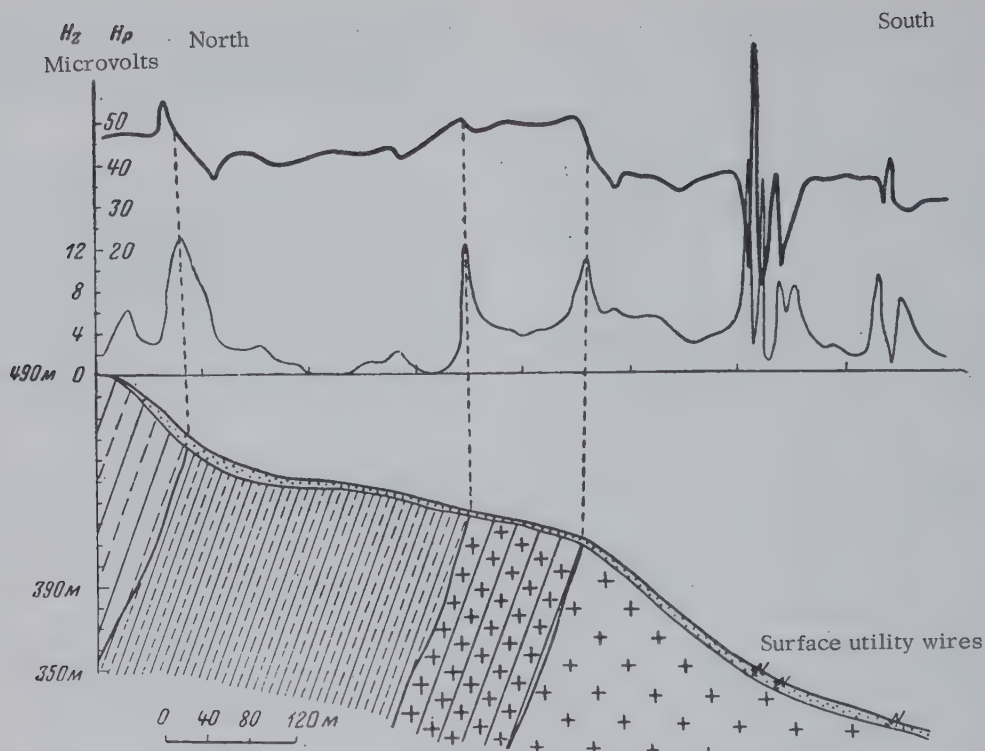
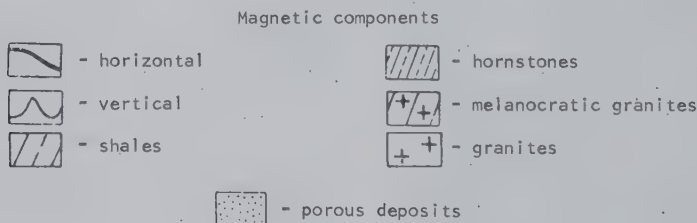


FIGURE 3. Results of voltage measurements of radio station field in Far East



mapping a definite universality. Even where there was a rather strong topographic relief along the profile, creating an anomalous background, it was possible to distinguish these anomalies from geological dissimilarities (see figs. 3, 5). Anomalies arising from electric and telephone lines are easily dispensed with so long as the operator notes their presence when walking the profile.

There is every reason to believe that the method of radio-wave geological mapping can be successfully applied in detailed mapping of contacts of dissimilar rocks in steeply dipping and displaced beds and also in mining veins of massive mineralization, ground-water lenses, and other geological dissimilarities concealed under porous deposits at depths of 15 m, 30 m

and in places more (depending on their resistance). The depth potential ascribed the method by S. M. Sheynmann [10] was less. This is evidently due to the fact that his use of the classical method of calculation of the field did not take into account all aspects of propagation and absorption of radio waves in the ground.

Considering the general principles of the formulation of frozen strata, we can state that there were very favorable conditions for the application of radio-wave method for mapping of their boundaries: a) almost exactly vertical and sharp (without gradual transition) contacts, b) significant differentiation as to electrical conduction [1] between frozen and thawed (porous, water-containing) rocks and also even between frozen rocks with differing

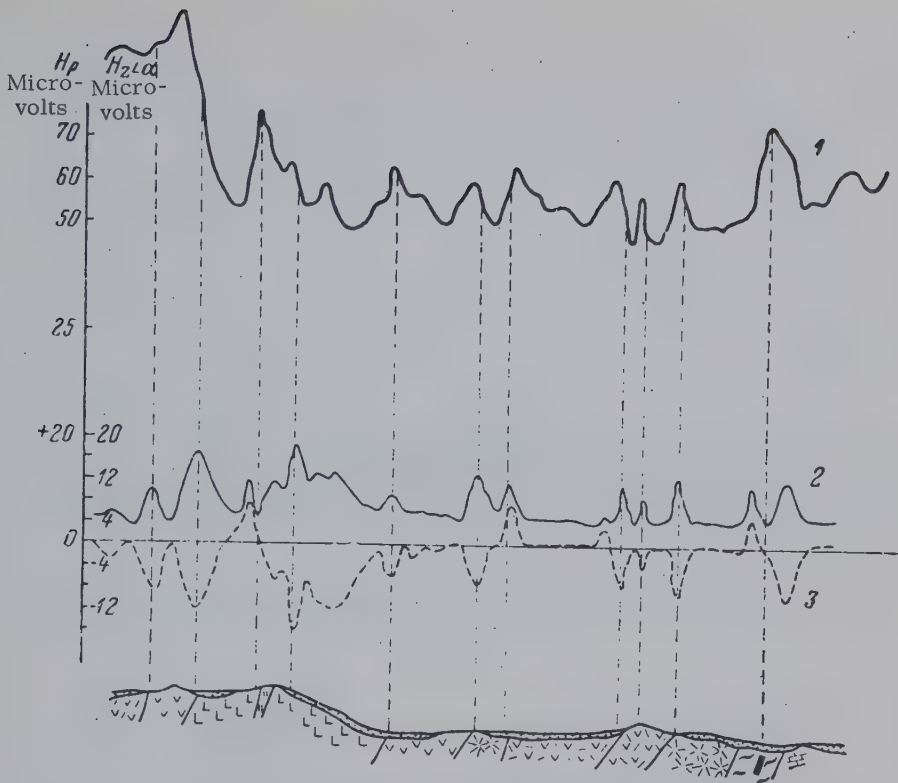


FIGURE 4. Results of voltage measurements of radio station field in Middle Asia

Magnetic components

1 - horizontal

2 - vertical

3 - angle of deviation of complete vector of magnetic component

content of ice.

In 1957 in the Far East we engaged in a small project on the use of the radio-wave method for mapping of contacts of rocks frozen for many years and of thawed rocks, the results of which confirmed the practical possibility of such mapping. It should be noted that the experiments were carried out under atypical frozen conditions, since mineral temperatures of the rocks in this district were minus 0.5 (rarely one degree C) and the thickness of the porous sedimentations consisted in most sections of 3 to 7 m (rarely up to 15 or 20 m). In spite of this we succeeded in obtaining meaningful results on several sections.

Figure 7 is a sample map of a profile of radio-wave measurements conducted on one of the river-valley terraces built up by boulder-sand-clay frozen deposits to depths on the order of 15 or 20 m. On all the profiles in its northern parts there were enough clear anomalies to fix the contact between frozen

rocks and thawed rocks. For interpretation of the anomalies in the southern parts of the profile small holes were drilled in profile 27 (fig. 7), at PK 7.5, PK 9.5 and PK 21). At PK 7.5 and PK 21 (Sh No. 4 and Sh No. 6, fig. 7, profile 2) no frozen rocks were detected to a depth of 3.7 m (maximum depth of hole), while at PK 9.5 (Sh No. 5) frozen rocks were encountered even at a depth of 2.3 m. Thus, the zone bounded by anomalies of an overlapping type was a section of increased moisture (ice), which depended on considerably less seasonal thawing, and that section was formed as if there was a vertical shelf of frozen rocks among the thawed ones. (The northern boundary is shown on all profiles on Figure 7, but the southern boundary, because of localities of many swamps which were impossible to measure and in view of the impassibility of the marshland, are registered only on profiles 2 and 3).

In the experiments in mapping frozen rocks this peculiarity was noted. Sections with

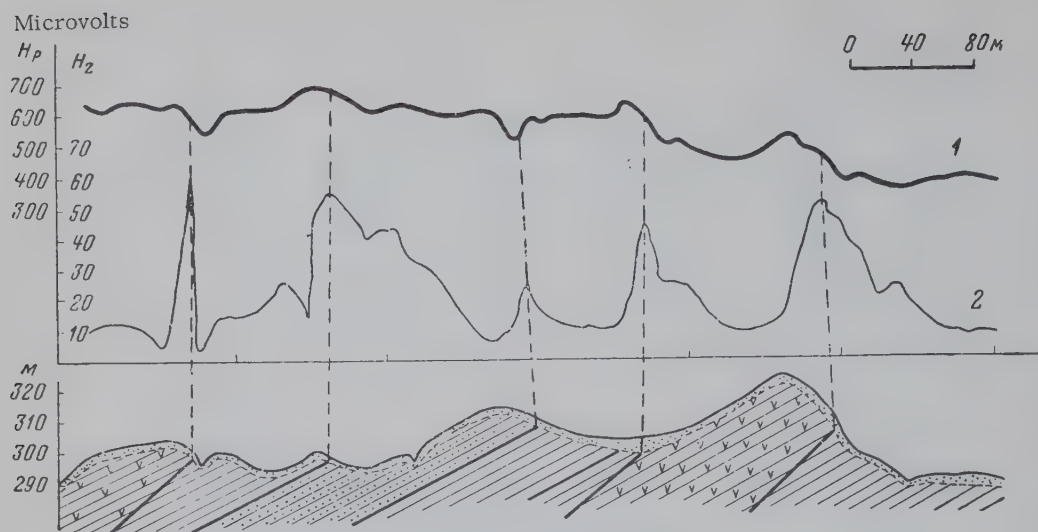
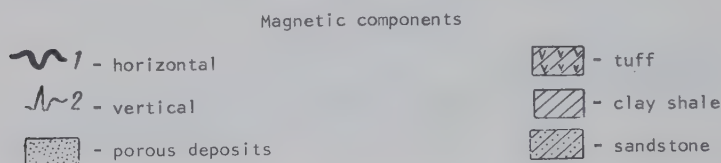


FIGURE 5. Results of voltage measurements of radio station field in the Ukraine



small thicknesses of porous deposits (5 to 10 m), where there was contact of frozen and thawed rocks, could not be successfully registered by the radio-wave method. However, as soon as the thickness of the porous deposits reached 15 m and more, it immediately became possible to register the contacts of frozen and thawed rocks for quite clear anomalies of the voltage of the radio field. This, evidently, could be attributed to the following. In the presence of small areas of moisture in the ore deposits the radio-wave field, penetrating through them, underwent relatively little absorption by them merely because up to two-thirds of the thickness of these deposits consisted of frozen rocks having higher resistance (consequently, less absorption). Thus, the basic part of the energy of the radio field penetrating into the ground will be diffused (absorbed) by the original rocks (slates, sandstones, granites) at a depth just below this and, consequently, the formation of anomalies will be chiefly influenced by the electrical properties of this stratum. However, in view of the small amount of ice (moisture) in the solid, original rocks, the difference in the electrical properties of frozen and thawed sections in these rocks is very negligible, and contact of frozen and thawed rocks did not cause anomalies in the voltage of the radio field. The above-mentioned peculiarity was a definite "minimal thickness" of the stratum in which there was contact of dissimilar rocks or, more generally, a "minimal vertical thickness" of the geological hetero-

geneities. The magnitude of this minimal thickness was apparently determined by the relationship and absolute value of electromagnetic parameters of the surrounding rocks and the heterogeneity itself. In the geological mapping of contacts of frozen rocks of long standing and thawed rocks by the radio-wave method in the more northern districts results should be considerably clearer, since under conditions of comparatively low temperatures of the frozen layer there will be a sharper difference in the electrical properties of frozen and thawed rocks, which was proved by our experimental studies conducted in 1959. Mixing porous deposits with this was not an interference, and the greater their thickness, the more possible the registration of this contact.

The application of the radio-wave method of mapping is especially promising in districts (taiga, steppe, desert) where transit is difficult and where establishment of investigations by other geophysical methods is laborious because of the complexity of their organization and technical completion. In addition, in most of the projects the thickness of the porous deposits in these districts did not exceed 10-15 m, but even those of greater thickness possessed high resistance (sand deserts), and because of poor exposure of the original rocks in the geological-surveying procedures much time and effort were spent on traveling through a large number of mountainous areas to determine contacts of dis-

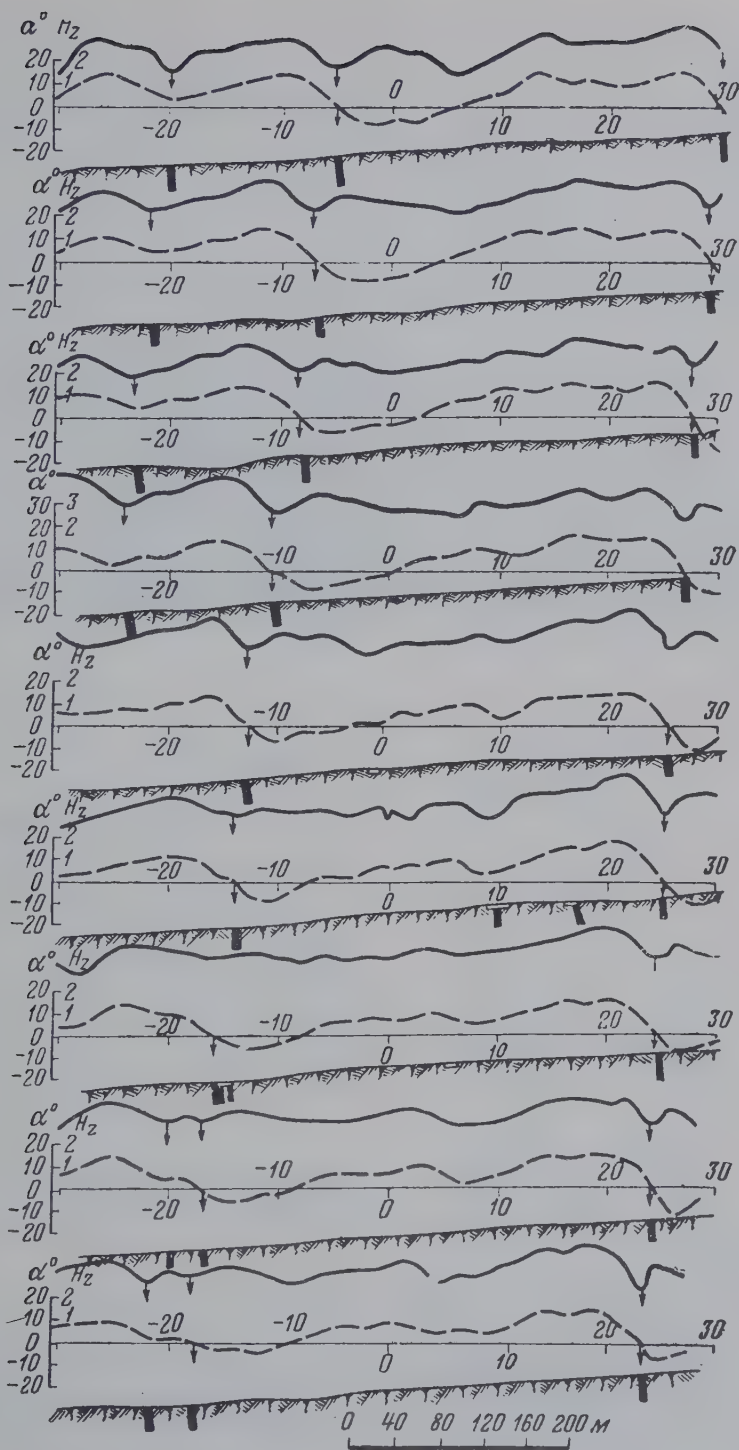


FIGURE 6. Results of geological cartography in Eastern Siberia conducted by the radio-wave method

— vertical magnetic component - - - angle of deviation of complete vector
of magnetic component
 - zones of disintegration

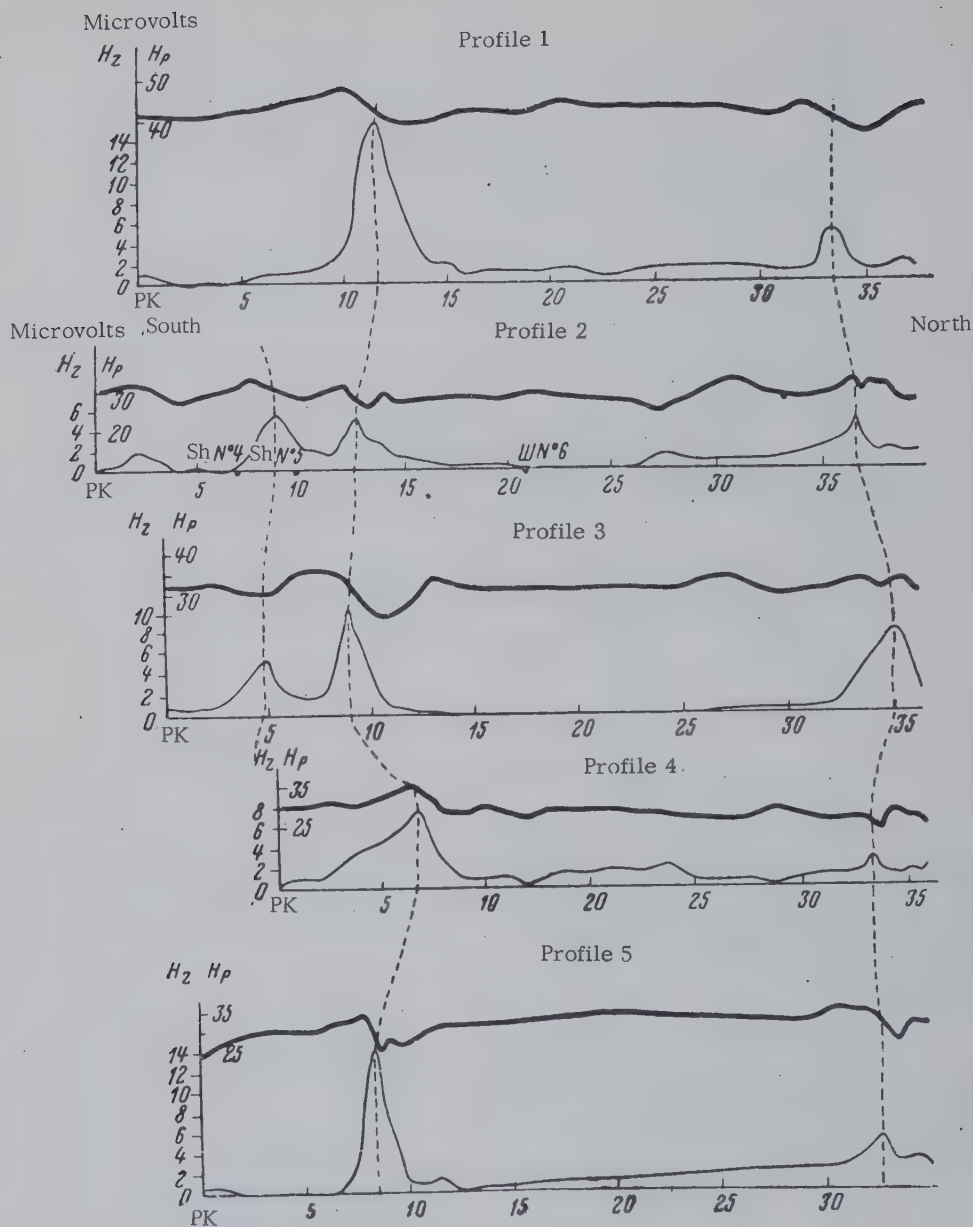


FIGURE 7. Results of work with radio-wave method on cartography of rocks frozen for many years in the Far East

similar rocks, zones of structural disturbances, etc. Simplicity and ease of conduction of field measurements and their interpretation in undertakings with the radio-wave methods in districts with difficult access are especially valuable. Nevertheless, the indicated method has not yet received wide recognition. The chief reason for this is the absence of a suitable field-measuring instrument which is simple in manipulation, reliable in its function, economical, portable, and light. The "Ruda" type of

apparatus, applied until the present time (a few experimental models in all), the IP-12M recorder of radio interference, and the like do not satisfy this basic requirement in practice.

The IP-12M instrument (fig. 8, a) is in essence a very imperfect apparatus for field work. Its design has a series of striking defects when used as a recorder of field voltage): nonsymmetrical opening, capacity of divider

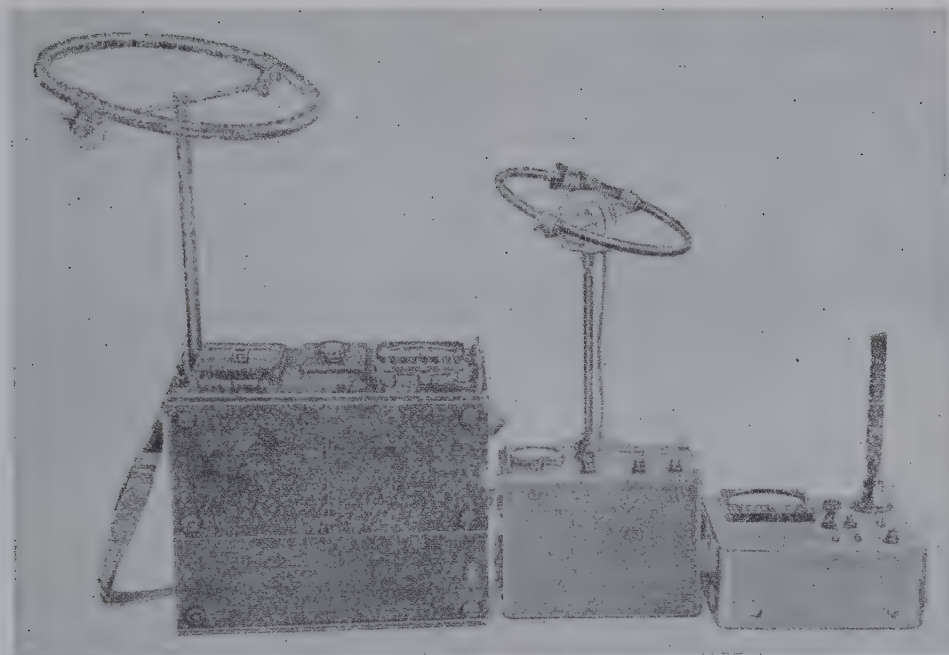


FIGURE 8. Instruments for completion of work by radio-wave method of geological cartography

on opening, markedly unlined detector, etc. The working antenna, which has to be made separately for the instrument, where it is to be used for field measurements of a radio field for geological surveying purposes, usually causes the voltage divider to be out of order if it is not equipped with a special built-in condenser to align the objects, and this highly complicates its construction. Only a well-qualified and proficient operator can manage successfully with the IP-12M instrument. Besides the operator one or two others are needed in the work with this instrument, because it weighs about 16 kg with the supply attachment, and one battery set (two BAS-G-U-80-2.1 and four 3S-U-30) is sufficient in all for from 20 to 25 hours' work.⁶

The "Ruda" model (in 1951) (fig. 8, b) is an experimental model of a field instrument for radio-wave cartography. It is considerably

lighter (weight with batteries 7.5 kg), is smaller in size than the IP-12M instrument and is suitable for fastening on the chest of the operator. However, there are also a number of essential disadvantages in the design and construction of this instrument. The sensitivity of the "Ruda" is only about 70 microvolts, and even the accuracy of relative measurements is low. The instrument is assembled on finger-like tubes for the first series of the IAP and IBIP types which have insufficient stability of the parameters and are of little value for a field instrument. It is not very economical; one supply outfit (two batteries BAS-G-U-90-0.6 and four elements 2S-L-9) takes care of from 25 to 30 hours of work. Besides, only a few models of the "Ruda" instrument were manufactured, so that for practical purposes it is unavailable.

In 1958 the manufacturers produced a series of the IP-12M radio interference recorders (IP-25), constructed with finger-like tubes of the second series (IK2P, IB2P, A2P) and small profile details [15] instead of the IP-12M. This instrument was much smaller in size and weight (9 kg with supply attachment) and also differed in having somewhat greater stability than the IP-12M. However, it also possessed the defects peculiar to the IP-12M. With the manufacture of small size magnetic antennae for this instrument it can still be used in works by the radio-wave method of mapping and more productively than IP-12M.

In 1958 while on the geological faculty of Moscow University we designed and built (jointly with G. M. Mikirtichan) a special field recorder of the voltage of the radio field (PINP-1) on semi-conducting triodes [8]. Development of the instrument was performed on the basis of experiments of long-established field works by the method of radio-wave mapping with a consideration of the basic, practical needs for this instrument. The developed instrument, assembled according to a super-heterogeneous [superheterodyne?] scheme on semi-conducting triodes [transistors?], is a highly selective microvolt meter capable of measuring from 3 to 100,000 microvolts with an accuracy of ± 10 percent in a band frequency of 150-450 hertz [150,000 - 450,000 cps]. The

instrument is equipped with a special revolving magnetic antenna, which can be used to measure the vertical and horizontal magnetic components, angle α , and elements of polarization of the radio field, and it has a needle indicator for measuring voltage and a loudspeaker for sound monitoring. A special scheme of temperature stabilization of the working point of the semi-conducting triodes is provided in the instrument, and this guarantees adequate functional stability in a temperature range of minus 20 to plus 39 degrees [Centigrade]. The PINP-1 instrument is a hundred times more economical [of electrical needs?] than the IP-12M and approximately 60 times more so than the "Ruda" and IP-12-2M. It functions from seven elements of the type I-KS-U-3.0 ("Saturn"), and one supply set is good for from 400 to 500 working hours.

The instrument with supply system is erected on a framework measuring 260 by 210 by 120 mm and weighs about 5 kg. It is suitable for fastening (with the help of shoulder straps) on the operator's chest. Working with the instrument PINP-1 is extremely simple, does not require special qualifications, and can be done by any geologist with the appropriate instructions.

After determination of the normal voltage supply (which should be checked 2 or 3 times during the working day) and tuning on the selected radio station, the entire recording process is reduced simply to the various revolutions of the magnetic antennae and to a recording of what the indicator voltmeter shows H_z , H_p , α and others with correspondingly placed antennae. No kind of regulation is required for the intensity, setting of zero on the voltmeter, frequent checkings of normal supply setup and so on, in working with the PINP-1 instrument. At the present time a few test models of the instrument have been manufactured (fig. 8, c); in the summer of 1959 they successfully passed the first field experiments in various districts of the Soviet Union. Results of these trials showed that the instrument had excellent exploitation qualities, was convenient and simple to work, and was superior in grade of measurement (see figures 4 and 5). Some imperfections in construction will be eliminated in new, modernized models of the instrument PINP-2, a small series of which were ready for the market in 1960.

The seven-year plan of development of the national economy of the U. S. S. R. calls for the conduct of large-scale geological surveys on the larger areas of our country in the near future. The question arises about the broad utilization in these works of geophysical methods of surveying which may contribute significantly toward expediting them and reducing their cost, especially in districts with a small outcrop.

The radio-wave method of mapping is the

easiest and most productive, and to some extent it is a general geophysical method. It can be widely and effectively used in geological surveying in districts of difficult access and a poor outcropping of rocks (tundra, taiga, steppe, desert) and in permafrost districts. In the surveying and mapping of mining elements one of the essential advantages of the radio-wave method of mapping (as also with the high-frequency method generally) is its applicability for objects not having a continuous union (phenocryst, porphyritic ores, etc.), where electrical curves with a constant current or currents of low frequency often cannot give desired results.

Besides the greater thickness and high electrical conductivity of porous deposits, a necessary condition limiting the application of the radio-wave method of mapping is the need to be able to tune in on some kind of long-wave radio station. In the European part of the U. S. S. R. there is no area where there is not at least one station which can be tuned in, and generally there are several.

Accumulated experience in the use of the radio-wave method of geological mapping and certain radiophysical ideas about the structure of the field of surface radio waves makes it possible to state definitely the practical possibility and potentiality of similar methods and apparatus for measurements of the radio field in motion, in particular the method for aerial-geological works. It is known [3] that the structure of the field of the long-wave radio station in a remote zone in the day time is such that a disturbance of the field, caused by geological heterogeneities, will be noticeable enough at least up to an altitude of $0.7 \pm 1\lambda$, and the vertical lapse rate of the field at altitudes of $0.2-0.3\lambda$ will be small. It follows that, in the aerovariant of the radio-wave method of geological cartography, it should be possible to conduct measurements at altitudes of several hundred meters (since the working lines of waves are $\lambda \geq 700$ m). Fluctuations in altitude (20 to 30 percent) will not cause marked interference, however, and this indicates the essential superiority of this method over other methods of aerial electro-surveying.

CONCLUSIONS

1. The radio-wave method of geological mapping can be successfully applied for rapid and accurate delineation of vertical and inclined contacts of dissimilar rocks, zones of structural disturbances, ore veins, and other geological heterogeneities under certain geological conditions.

2. The application of this method is especially effective in geological surveying projects of an average and large-scale nature in poorly accessible terrain (tundra, taiga, dry steppes, frozen regions, etc.), where a sparse out-

cropping of the country rock is combined with relatively small (usually up to 5 - 15 m) thicknesses of porous overburden or deposits sharply contrasted to it (sand deserts). Here is a possibility for the construction of an apparatus and the development of an aerial variant of the radio-wave method of geological mapping.

3. Utilizing transistorized instruments, the field recorder of the voltage of the radio field (PINP-1) gives a firm basis for the widespread introduction of this method of radio-wave geological mapping in the practice of geological surveying expeditions. If expeditions are provided with such instruments, it may be possible to make impressive reductions in the time and expense by eliminating the need for many exploratory pits and wells and other methods requiring highly specialized personnel.

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THERMAL WATERS OF THE PALEOZOIC AND MESOZOIC IN THE WESTERN PART OF THE CRIMEAN PENINSULA¹

by

M.M. Germanyuk²

ABSTRACT

The geology, tectonics and hydrothermal regime of the western part of the Crimea peninsula are summarized. Exploratory wells drilled in the Novoselovsk and Saki platform structures show two anticlines with a depression between. The rocks involved are metamorphic products of limestone, clay, sandstone, and conglomerate, all overlain unconformably by a rather uniform sequence of Miocene clays. Faulted Neocomian rocks, overlying the Paleozoic basement, are the most productive of thermal waters relatively low in mineral content. The Crimean hydrothermal regime is compared to those of Groznenskiy, Krasnodarskiy and Azerbaidzhan. --A. Eustus.

* * *

In 1955-56, exploratory wells for petroleum and gas were drilled in the western sector of the steppe part of the Novoselovsk structure and the Saki uplift. Two key wells were drilled near Tarkhankutsk and Dzhankoy. All these wells revealed a geological sequence of metamorphic formations which indicate the presence of strata ranging from the Paleozoic to the Miocene.

Preliminary investigations of Paleozoic and Mesozoic members of Novoselovsk highly mineralized hot water with a considerable flow rate. Slightly saline water under high pressure was also discovered in the Saki uplift, 30 km to the south. Geothermal studies were carried out during drilling operations.

Thermal waters discovered in Paleozoic and Mesozoic metamorphic rocks are significant.

The Novoselovsk structure extends over three neighboring districts of the Crimean region: Evpatoriya, Pervomayskiy and Saki. Thirty-five northeast of Evpatoriya, on the crest of the structure, test holes were drilled to depths of 1, 100 to 2, 536 meters along a north-south profile (Novoselovsk 1, 3, 4 and 9) and an east-west profile (Novoselovsk 7, 8 and 9).

The older layers in the structure were gray and dark gray compact crystalline with yellow-gray crystalline schists which included dikes of diabasic porphyry and quartzite porphyry. According to measurements made in Novoselovsk well no. 3, these layers attain a thickness of 1, 200 m. These metamorphic rocks are Paleozoic.

The Jurassic layers include light gray with

greenish marble, interbedded with conglomerates, massive sandstone and dark clayey schists. Gabbro diorites up to 20 m thick occur. According to data from Novoselovsk 1, these strata are 400 m thick; at Novoselovsk 3, 130 m. They are missing in the crest of this structure (Novoselovsk 4, 7, 8 and 9).

Above the layer of marble there are Cretaceous deposits the lower part of which consist of sandstone, argillites, and dark gray limestone clays interbedded with fine-grained quartzitic sandstone, limestone and marl with a total thickness about 100 m. Cretaceous clay deposits of the Albian-Aptian occur in the middle part with occasional interbeds of marl 500 to 600 meters thick. The upper Cretaceous consists of light-gray, fine-grained marl interbedded with gray limestone varying throughout the structure from 10 to 620 m. Eocene marl and marly clays with occasional bands of fine grain sandstone were encountered only in Novoselovsk 3.

All the borings revealed Miocene strata at the upper level, mostly sand, oolitic limestone, and clays, with a total thickness of 130 m. Structural and exploratory boring data showed that the Novoselovsk structure is a major platform-type anticline fold extending east-west. Two elevations are located within this structure: the larger, the South Novoselovsk structure, well defined by the Saratian, Upper and Lower Cretaceous, (Albian-Aptian) deposits, and the North Novoselovsk structure, characterized only by lower Saratian and Upper Cretaceous.

The two folds are separated by a relatively narrow depression filled by Maikopian and Eocene deposits (fig. 1).

Aquifers in the Paleozoic and Mesozoic strata in the Novoselovsk structure were probed by drilled test holes. Mineralized water was obtained only from well No. 3. Table 1 gives the water analysis.

Chlorine-calcium-type waters from Paleozoic and Jurassic beds had a total mineral

¹Translated from: *Termalnyye vody zapadnoy chasti Krymskogo poluoostrova*, Sovetskaya Geologiya, no. 6, 1960, pp. 111-118.

²Southeastern Karakutsk Expedition

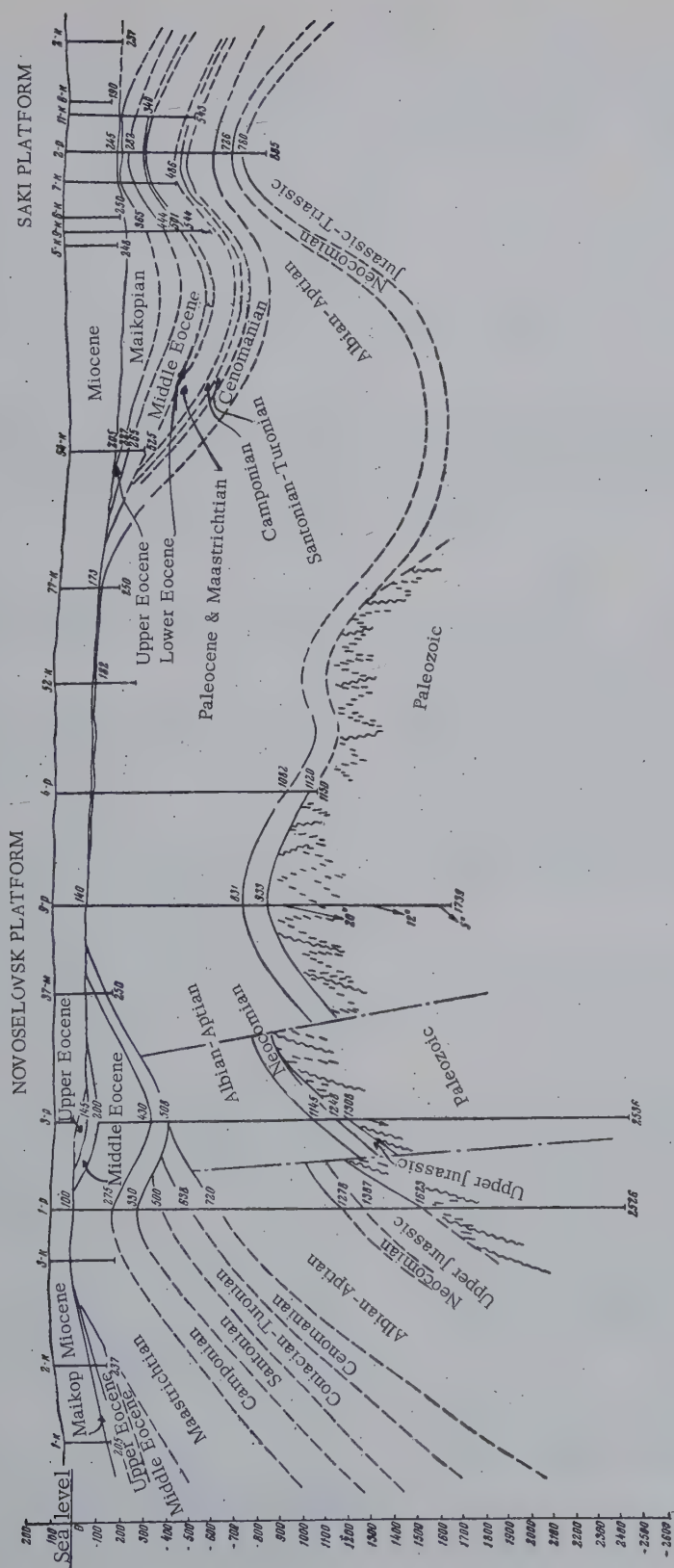


FIGURE 1. Geological cross-section through the Novoselovsk and Saki platforms (by A.P. Osipovskii)

TABLE 1

Internal between strata and age of formation	Rate of flow m ³ /day		Well mouth Pressure atm	Temperature °C		Type of Water	Mineral-ization	Content mg/l			Comments
	Water	Gas		Deep level	Mouth			I	Br	Naphthenic acid	
Paleozoic 2506-2482 m,	5.7	insignificant	9	99.1	-	Calcium Chloride	38.8	9.3	77.9	0.8	Weak overflow well mouth
2468-2453 m,	8.6		-	98.3	19		38.9	12.7	82.7	0.8	
Jurassic(?) 1245-1225 m	40		7	65.1-64.3	26		33.04	10.6	77.5	0.6	

content of 33 to 39 g/liter. Iodine, bromine, naphthenic acids and ammonia were present. These waters did not occur in any great amounts and their temperature was low at the lower level of the well. In view of their deep occurrence, these waters probably have no economic value.

Thermal waters which had seeped to the level of the Neocomian were encountered in all wells drilled through the Novoselovsk structure.

Table 2 gives the subsurface recordings taken from Novoselovsk 4 indicating maximum flow, pressure and maximum temperature ranging from 1021 to 1023 m. Novoselovsk 9 is next in flow rate, pressure and temperature. The rate of flow in the other wells was quite insignificant. It should be noted that the potential, particularly for Novoselovsk 3, 4, 7, and 8 is not limited to flow obtained so far, since the test period was short and the flow might increase significantly from additional wells.

The Saki uplift is located at the city of that name. Two wells were drilled here: Saki 1, on the northwestern slope, to 1467 m, and Saki 2, at the top of a dome, to 885 m.

Much older deposits dating back to the Tauridian (Upper Triassic and Lower Jurassic) and penetrated by two wells are represented by dull dark clayey carboniferous schists with carbonized plant deposits interbedded with quartzitic sandstone, siltstone and occasional limestone. At Saki 1 they reached a maximum thickness of 543 m. Above this level there is a Neocomian bed up to 80 m thick consisting of variegated deposits and light-gray, fine- and medium-grain sands and siltstone with fine gravel interbedded with dark-gray sandstone clays with lignite and siderite.

In comparison with the Novoselovsk sequence, the Albian-Aptian dark-gray clays and argillites are no thicker than 280 m at well No. 1, and 70 m in well No. 2.

Above this level there are some Upper Cretaceous formations represented by light-gray

marl. This marl is 105 m thick at well No. 1 and 78 m thick at well No. 2. Tertiary strata up to 190 m thick overlying Upper Cretaceous formations include Eocene marl and marlitic clays, as well as Maikopian clays 10-20 m thick and Miocene deposits of the Second Mediterranean stage up to the Pliocene.

According to seismic data, the Saki uplift is of broad extent, rising to the ESE towards the Simferopol' uplift and plunging to the north, west and south.

Borehole studies were carried out for the Tauridian, Lower Cretaceous, and Albian-Aptian layers. Test results and notes on the waters are given in Table 3, which shows that the greatest water flow of well No. 2 came from the Neocomian. The water is slightly saline, but potable. Waters from the Tauridian and the Albian-Aptian are of little value because of their low rate of flow. It should be noted that there is an overall increase in the general mineral content of Lower Cretaceous waters and in their iodine, bromine, naphthenic acid and ammonia content. A sodium hydrocarbonate content gradually changes to one of magnesium chloride and calcium chloride.

This pattern of general increase of the total mineral content of water from south to north indicates the general direction of the movement of underground water through Neocomian deposits as from SSE to NNW; that is, the waters emerge from the foothills where Lower Cretaceous as well as older formations outcrop.

The postulated fault formations in this region do not exclude the possibility of also finding thermal waters in deeper strata. Presence of such waters was established by Novoselovsk 3, drilled through the Paleozoic and Jurassic, and by Saki 1, through the Tauridian.

In the thermal waters of both structures there is an insignificant amount (up to 200 cubic meters per day) of hydrocarbon gas, which emanates freely from the water and is combustible when separated. According to the analysis of the VNIGNI Gas Laboratory, this gas contains

TABLE 2.

Well number	Interval layers, m	Rate of flow m ³ /day		Pressure at the well mouth, atm	Temperature °C		Type of Water	Mineral-ization	Content mg/l				Comments
		Water	Gas		Deep level	Well mouth			I	Br	NH ₄	Naph-thenic acid	
1	1378—1291	225	200	0.5	68.5 66.5	53	Calcium chloride	37.88	11.5	81.5	—	0.8	Overflow at well mouth
3	1158—1140	80	Insignif-icant	—	—	—		33.81	9.8	71.1	56.3	—	
9	925—915	70	None	—	—	25		12.1	3.8	24.9	37.8	0.2	Weak overflow
9	887—885	36		—	—	29		12.54	4.6	26.6	46.4	0.2	
4	1132—1138	5		—	—	20		14.5	—	—	—	0.4	Gushing
9	840—816	430	200	7	—	50		12.52	4.5	28.6	46.0	0.28	
4	1023—1021	1130	Trace	13	—	58	Sodium bicarbonate Magnesium chloride	9.6	4.4	8.3	18.6	0.3	Overflow at well mouth
8	1121—1110	47	None	—	—	38		16.98	4.8	36.4	74.4	—	
8	1095—1090	14.5	100	—	—	25		16.8	3.9	29.2	78.5	None	Gushing
8	1073—1065	7.7	Insignif-icant	—	—	29		16.99	4.3	31.6	74.5	—	
7	1132—1114	86.4	None	—	—	41		9.12	3.3	19.7	52.6	—	Gushing
7	1097—1079	19		—	—	24		8.63	2.7	20.6	42.5	—	
7	1030—1022	172		—	70.1	50		7.6	3.1	13.2	6	Trace	

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TABLE 3.

Well number	Depth of occurrence	Type of formation	Rate of water flow m ³ /day	Pressure at well mouth atm	Temperature		Mineralization g/L	Microcomponents mg/l			Comments
					Recorded range	Well mouth		I	Br	NH ₄	
1	1469-1010	Tauridian series	14	-	-	22	5.8	0.6	5.7	8.4	Weak overflow
1	915-897		12	-	-	22	3	1.3	1.7	5.7	
1	855-860	Neocomian	36	-	46.6-45.7	-	3.1	-	12.7	-	Overflow with small amount of combustible gas
1	845-828	Neocomian	14.4	-	45.5-45.1	-	2.02	-	-	-	Overflow
1	523-500	Albian-Aptian	14.4	-31.3	-30.1	21.0	3.7	-	-	-	
1	808-799	Neocomian	15.8	-42.5	-42.4	22.0	2.65	-	6	-	
2	756-754		2500	12.04	41.8-41.3	28.0	1.87	1.87	-	-	Gushing

Note: All samples of NaHCO₃ type

TABLE 4.

Well	Temperature in °C recorded at given levels		
	500 m	1000 m	1500 m
7 Novoselovsk	42.8	69.3	-
1 Novoselovsk	38.6	56.8	71.5
1 Saki	36.9	49.5	-
2 Saki	36.3	-	-
Tarkhankut key	32.1	47	60
Dzhankoy key	31.7	51.5	71.2

TABLE 5. Geothermal steps and gradients computed as recorded for the deposits

Well	Tertiary		Upper Cretaceous		Lower Cretaceous		Jurassic		Paleozoic		Average value	
	m/°C	°C/100	m/°C	°C/100	m/°C	°C/100	m/°C	°C/100	m/°C	°C/100	m/°C	°C/100
Novoselovsk	1	26	3.7	26.1	3.7	31.1	32	41.5	2.4	34.5	31.6	3.1
	7	12.1	8.6	-	-	19.5	5.1	-	-	-	18.2	5.4
Saki uplift	1	37.7	2.6	47.7	2.2	40.0	2.5	36.4	2.7	-	38.7	2.6
	7	31.9	3.1	40.4	2.4	49.3	2	61.8	1.5	-	38.6	2.6
Tarkhankut key well	28.2	3.5	37.6	2.6	-	-	-	-	-	-	33.8	2.9
Dzhankoy key well	27.9	3.6	20.4	5.0	-	-	-	-	-	-	27.1	3.7

not more than 62 percent hydrocarbon, not more than 60 percent nitrogen and a small amount of carbonic acid. The results of geothermal observations from wells in the Novoselovsk and Saki platforms, and Tarkhankut and the Dzhankoy key wells are shown on Figure 2.

The determination of the geothermal stage and the gradient was carried out as a rule by means of boring pipes which remained in position for periods ranging from 8 days (Saki 2), up to 20 days (Tarkhankut key well). According to Table 4, the highest water temperature was

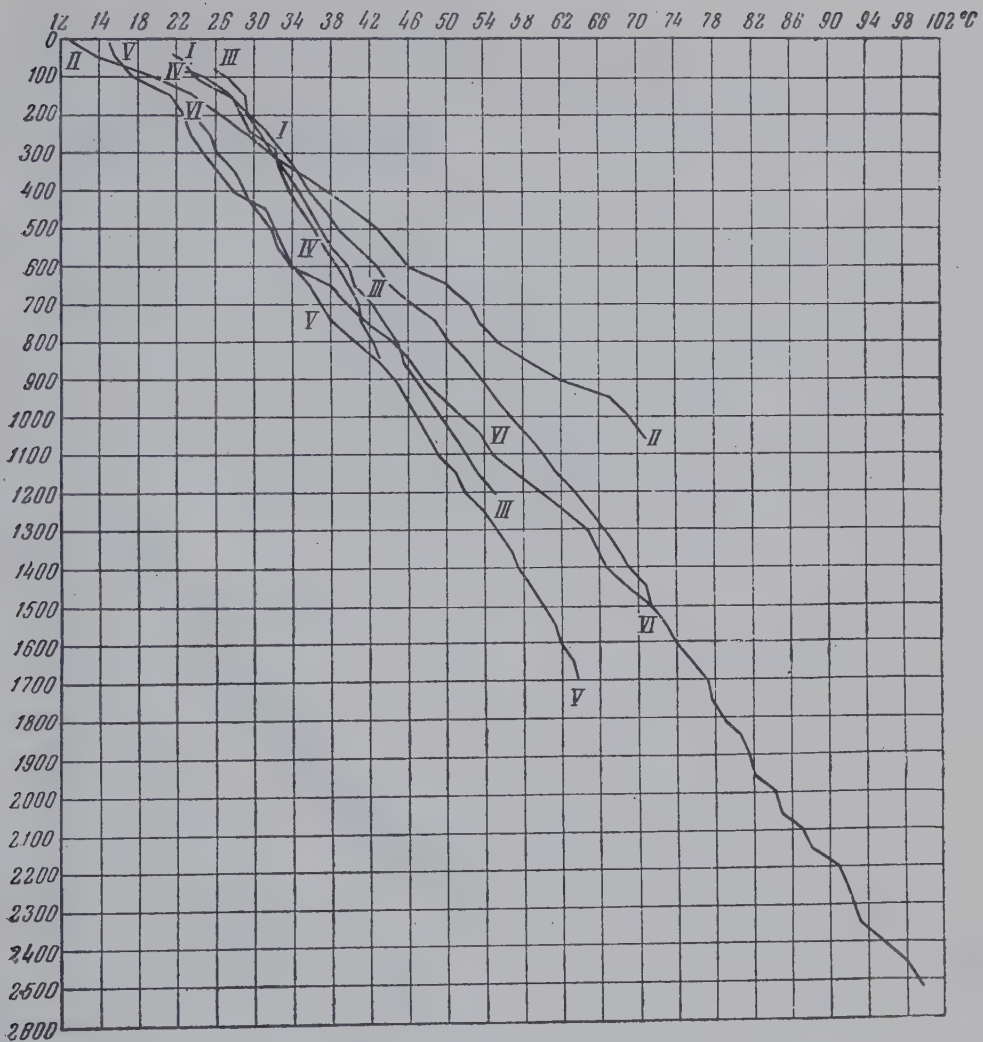


FIGURE 2. Temperature curves for the different wells

1 - Novoselovsk 1

2 - Novoselovsk 7

3 - Saki 1

4 - Saki 2

5 - Tarkhankut key

6 - Dzhankoy key

observed in Novoselovsk 7. The decrease in the temperature of the mineralized thermal waters when rising to the opening of the well is not constant. Thus, in Novoselovsk 1 the temperature decreases by $13\frac{1}{2}$ degrees over a distance of 1300 m; in Novoselovsk 7, through the same diameter, the temperature decreases by 19.9 degrees over a distance of 1022 m, while in Saki 2, it decreases by 13.8 degrees over a distance of 750 m. On the basis of temperature readings in the wells at the same absolute level (-1000 m), we established a schematic map of the geoisotherms of the steppe region of Crimea (fig. 3). It appears from this map that there is a geothermal dome with a maximum temperature of 73.2 degrees within the western steppe of the Crimea on the Novoselovsk structure. This dome reflects generally the structural char-

acteristics of the Novoselovsk uplift and the emergence of this dome is explained by the presence of thermal mineralized waters in the Lower Cretaceous. A listing of the geothermal steps and the geothermal gradient according to the measured intervals is given on Table 5.

Borehole and well studies in the Novoselovsk structure and the Saki uplift the western Crimean Peninsula, establish that:

1) The presence of strongly mineralized thermal waters with iodine, ammonium bromide, and naphthenic acid in the Paleozoic and Jurassic layers of the Novoselovsk structure. In view of their great depth and insignificant rate of flow, these waters from the Tauridian (Albian-Aptian) of the Saki uplift have no practical value.

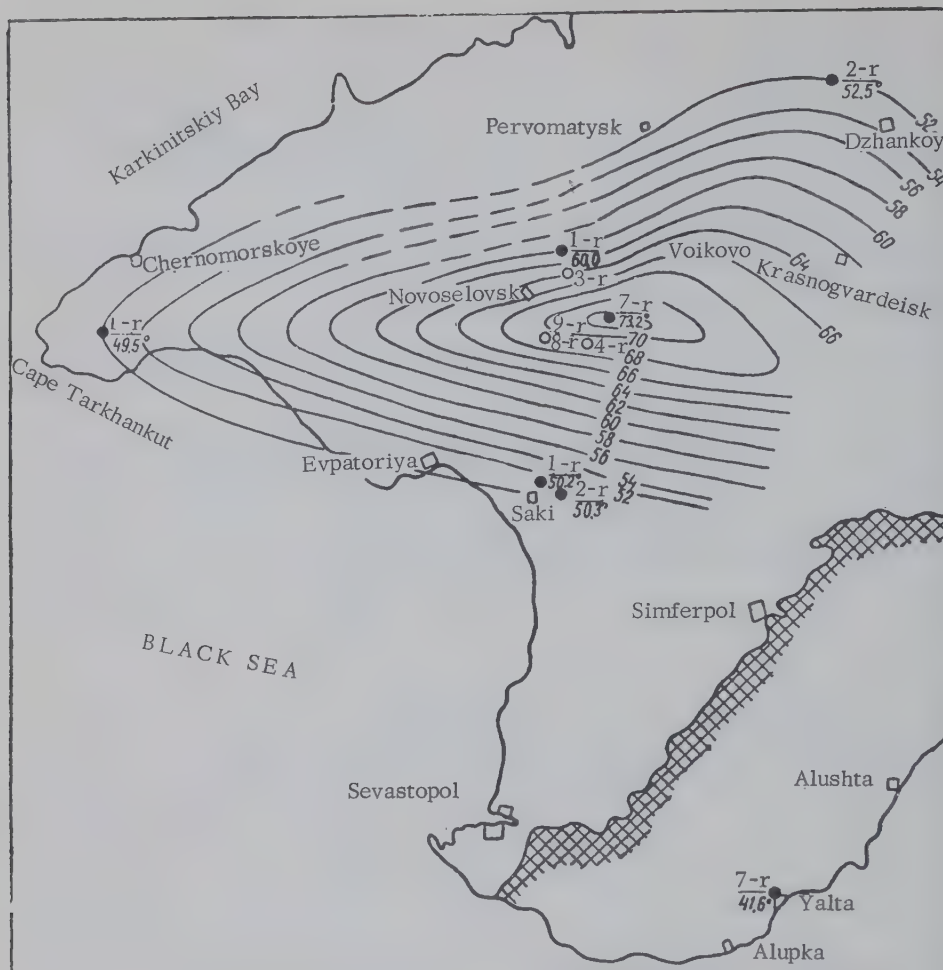
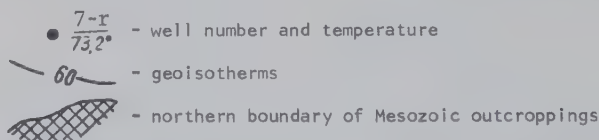


FIGURE 3. Map of geoisotherms as recorded at -1000 m in the western part of the Crimean Peninsula



2) Significant flow from thermal wells was discovered in Neocomian deposits of Novoselovsk. These waters are highly mineralized with iodine and bromide and could be used for bathing purposes (for spas), for heating plants, green houses, steam generators and heating purposes. The explored area of the aquifers extends over almost 300 km².

3) The waters of the Neocomian deposits in the Saki uplift are slightly saline and have a significant rate of flow. They could be used as mineral waters. The discovery of very slightly saline, almost fresh, water in the Neocomian deposits in the Saki uplift opens up the possibility of exploiting this resource in the Crimean foothills region.

4) It is apparent from the comparison of the geothermal gradient of the western Crimean Peninsula with that of districts elsewhere that geothermal conditions in Crimea resemble those of the Groznenskiy, Krasnodarskiy and Azerbaidzhan regions [1] and differ significantly from those of the western slope of the Ural [2].

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EMPLOYMENT OF GAS LOGGING IN PROSPECTING OPERATIONS¹

by

G.A. Mogilevskiy²

ABSTRACT

Gas logging may be used for the geochemical study of exploratory and other wells in prospecting for oil and gas pools in deep deposits. The analysis of gas logging data in known oil and gas deposits makes it possible to observe definite regularities in hydrocarbon-gas distribution that are associated with the process of the migration of these gases. The most important elements in the hydrocarbon characteristics of gas logging are: the depth of the first appearance of hydrocarbons in the well, the magnitude of the concentration gradient, and the shape of the hydrocarbon curve. Quantitative changes can be noted between the gas logging data of areas with the more permeable rocks of Tertiary and Cretaceous age and areas composed of more dense and less permeable strata of Paleozoic age. In the Stavropol province, Stalingrad region, and in western and eastern Siberia, studies of gas-logging data show the following: In structures containing significant accumulation of oil and gas, the hydrocarbon gases produce maxima in the crests of uplifts and minima on the flanks. These maxima have been traced in different stratigraphic horizons, and their intensity diminishes towards the earth's surface. In structures with insignificant accumulations of oil and gas, the hydrocarbon maxima are either poorly developed or absent entirely.

Also observed is a zonal distribution of nitrogen and carbon dioxide depending on the structural elements of the uplift. It is necessary to improve the apparatus used in core sampling and gas analysis. Apparatus used in gas analysis should be capable of fractional determinations of heavy hydrocarbons to within hundredths and thousandths of a percent. It is also necessary to be able to determine methane and nitrogen over a wider range of concentrations. -- Auth. English Summ.

* * *

In its original form, the method of gas logging was intended chiefly for identifying producing beds in wells being drilled for oil and gas. These problems, which can be considered as pertaining to exploratory work in oil fields, have determined the fundamental nature of subsequent gas logging operations.

Gas logging of wells by means of the episodic desorption of gas from drilling mud was first carried out in 1934 at the Achi-Su deposit by M. I. Bal'zamov. Somewhat later another method of gas logging was developed in the U. S. S. R., to aid in prospecting for oil and gas. This variety of the method, entitled gasometry, was proposed by the author in 1935-1936 as a means of gas surveying in depth [1] (V. A. Sokolov, 1930).

Well gasometry is used to determine the presence of highly gas-saturated sections of rock of the upper sedimentary series for prognosis in depth and for comparative evaluation of the gas saturation of individual sections or structures, in order to select the most promising direction of exploratory operations.

Gasometry (gas logging in prospecting) can be applied in the structural mapping of wells and detonation holes of seismic prospecting, as well as to stratigraphic wells and exploratory wells being drilled in new districts [2].

The principal manner in which gasometry differs from oil-field exploratory logging lies in more complete degasification (degazatsii) of the drilling-mud samples and core samples, and in the opportunity for subsequent full determination of all the principal components of the extracted gases on the VTI (ORS II) and TG-512 instruments and on a general-purpose chromothermograph, as well as on other instruments used for micro- and macroanalysis. Well gasometry is at present being carried out by means of the episodic selection of drilling fluid samples and their analysis under laboratory conditions, due to the fact that the available gas-logging stations do not provide for the "deep" degasification of drilling mud, and consequently do not provide an opportunity for determination of the microconcentrations of hydrocarbon gases and some other components.

¹Translated from *Primeneniye gazovogo karotazha v poiskovykh tselyakh*: Sovetskaya Geologiya, 1960, no. 6, p. 119-128. Footnote to title in Russian edition reads, "Paper presented by author at the 21st International Geological Congress, and recommended for publication by the National Committee of Soviet Geologists," however this is not evident from the Program, Volume of Abstracts, or Reports of the Congress.

²All-Union Petroleum Scientific Research Institute of Geological Exploration.

Well gasometry operations have, in recent

years, been carried out in the regions of the Northern Caucasus, East and West Siberia, Central Asia, Bashkiriya, in Saratov, and on the Ukhta. In the majority of instances, positive results were obtained. The aim of the present work is to discuss some of the most important questions that have arisen in connection with the well gasometry process.

This work sets forth the results of research on the subject carried on within the VNIGMI with the participation of B. S. Cherkin-skaya, A. N. Sukhovaya, K. P. Tokarev, et. al.

The employment of gas logging in prospecting operations is based upon processes of the migration of hydrocarbon gases from producing beds into the zone of surficial deposits. Such migration, proceeding in various ways, has taken place in the geological epochs gone by and is taking place at the present time (contemporaneous migration and paleomigration). The character of the gas migration, and the scale upon which it takes place, can be determined in general terms by means of the gasometry of wells that are drilled to the point of opening up the principal production beds. The results of well gasometry can be used as parametric data which establish the possibility of using geochemical methods in a district, and which facilitate interpretation of the data obtained.

The most important parameters for the gasometry of wells with respect to evaluation of the scale of hydrocarbon migration are: the initial depth of the occurrence of hydrocarbons in the profile, the value of the concentration gradient, and the shape of the hydrocarbon curve. The rules governing the variation of hydrocarbon concentration, outwards from the center of the deposit to its periphery, are also of interest.

The analysis of gas-logging curves, which show the extent to which hydrocarbon concentration varies with depth and with the other parameters indicated above, makes it possible to subdivide the areas of application of geochemical exploration into two principal groups: in the first of these may be included those cases where geochemical anomalies are formed as a result of the direct penetration of hydrocarbons from productive beds into overlying beds; the second group pertains to those cases where the formation of geochemical anomalies takes place as a result of hydrocarbon emanations from noncommercial accumulations of oil and gas which have originated in intermediate rock strata as a result of paleomigration and other processes.

These two groups can be divided in their turn into individual subgroups that correspond to various ages of the rock under investigation. In the gas-bearing districts of Stavropol, hydro-

carbon gases are, in the case of deep degasification, registered in macroquantities above known gas deposits within the limits of the first 25 m, the curves which characterize the behavior of hydrocarbon gases having a tendency to rise continuously with the depth (North Stavropol and Snegilevskoye deposits). Under the same conditions of desorption and analysis, the appearance of hydrocarbons above oil deposits in platform regions is registered at considerably greater depth: sometimes at 200 m and more (Archedinskoye deposit). Along with this, in the case of the presence of intermediate gas accumulations in Jurassic deposits (Korobkovskoye deposit), hydrocarbons are detected in drilling mud and in core samples at a comparatively shallow depth (approximately 50 m). Under the conditions of Western Bashkiriya and Tatarsiya, the analogous role of intermediate gas and oil accumulations is played by Permian accumulations of gas and oil with respect to the principal Carboniferous and Devonian oil deposits. They facilitate the opportunity for carrying out geochemical research here.

Consequently the assertions of some investigators, that above platform-type oil and gas deposits the migratory hydrocarbons do not reach the surface layers of the earth, appear in our view to be erroneous. As a result of rock-jointing phenomena and paleomigration processes, noncommercial accumulations of oil and gas that are genetically linked to commercial beds in the underlying deposits develop in the sedimentary nappe of the upper zone. Therefore, geochemical methods can be used with effect not only in geosynclinal regions, but also in many platform-type districts. Specific indications as to the possibility of applying geochemical methods in such districts can be obtained by means of the gasometry of parametric and other wells.

On the basis of data as to the depth of occurrence of the hydrocarbons and the manner in which the gasometry curve changes, it is also possible to ascertain in what wells and to what depth the geochemical research should be carried on. In regions belonging to the first group, all types of wells may be used for gasometry; in regions of the second group, this possibility is determined by the presence and depth of occurrence of intermediate gas and oil accumulations.

As a result of the comparison of averaged gas-logging data with materials provided by a study of the structural elements of drilled areas in districts of Stavropol', West Siberia, and East Siberia, the following relationships become apparent.

1) Hydrocarbon gases form maxima in the crests of structures containing commercial deposits of oil and gas, and minima at their

flanks. These maxima can be traced within the boundaries of various stratigraphic series. Their intensity diminishes with a decrease in depth.

Hydrocarbon maxima are either feebly expressed or entirely lacking in the crests of structures not containing commercial accumulations of oil and gas.

2) In contradistinction to the hydrocarbons, acid gases are encountered in the greatest amounts in the limbs, and in the least amounts in the crest portions, of structures containing commercial accumulations of oil and gas. At structures lacking oil and gas, acid gases frequently yield uncharacteristic curves. It has in general been noted that the higher concentrations of carbonic-acid gas are to be found in gas- and water-bearing strata, while the lower concentrations are restricted to dry horizons. According to gas-logging data, the content of acid gases is lowest in rock containing productive gas-bearing strata, and is as a rule highest in petroliferous rock (in many instances on account of hydrogen sulfide).

3) The greatest quantities of gaseous nitrogen are registered by gas logging in the portions of gas and oil deposits that lie near their contours [oil-water contact] (or near their crests); in structures where in commercial accumulations of oil and gas are lacking, nitrogen gas is registered predominantly near the arch of an uplift.

The nitrogen content is higher in intervals containing commercial oil or gas, than in water-bearing or dry strata. This difference is, however, not expressed with good contrast.

Experimental projects in the core gasometry of holes at the Kugultinskaya, Zhigalovskaya, and other areas have shown that nitrogen maxima can also be traced in a zone of shallow-lying deposits. In these instances nitrogen can be used as an indicator of structure. Data of aqueous gas-biochemical surveying, and of the gasometry of detonation holes, confirm the fact that the zonal distribution of hydrocarbons, nitrogen, and carbon dioxide is traceable in shallow-lying deposits as a function of the structural elements of uplifts. Thus hydrocarbon gases, nitrogen, and, in a number of districts under conditions of flooded strata also carbon dioxide may be used in the conduct of well gasometry as indicators of the deeper presence of oil and gas.

Comparison of gas-logging data with the results of well sampling carried out at many wells of the North Caucasus regions, the Tyumen'skaya and Om'skaya oblasts, the Altai, and Northern Kazakhstan shows that hydrocarbon gases contained in the tested strata are reflected through gas logging with the limits of 3-4%, whereas nitrogen and carbon dioxide are, on the contrary, registered in quantities that

exceed ten times the percentage content of these gases in the stratum itself. Here the degree of completeness to which the presence of hydrocarbon gases is manifested turns out to be higher in those depth intervals where nitrogen and the acid gases have lower mean concentrations, and, conversely, the relative share of combustible gases diminishes as the percent content of the incombustible components increases.

The dissolution of stratum gases in eluate apparently acts in different ways upon the individual components of natural gas, as well as upon their relationships. As a result of this process, a redistribution of the gases takes place, and the combustible fraction is, as a rule, diminished on account of the incombustible components. This circumstance points to the necessity for thorough study, by means of gas logging, of all components of the natural gas that is present in the eluate, with the aim of eliminating the factors that hinder a more complete reflection of the content of methane and the heavy hydrocarbons.

The excessive content of nitrogen and carbon dioxide in the eluate, in comparison to their concentrations in gas-, oil-, and water-bearing strata, cannot be explained only by the sorptive capacity of drilling mud or by a high background content of these gases in the initial water and in the clay from which the drilling mud is prepared, nor by methodological errors in desorption and analysis. All these factors affect to a certain extent the excessive values of the quantities determined for nitrogen and carbon dioxide. However, the principal reason for the high concentration of incombustible components in drilling mud is the higher content of these gases in enclosing rock, as compared to their concentration in gas- and oil-bearing horizons and in the gas- and water-bearing ones.

This supposition is supported by the comparative examination of gas-logging data and the results of hole sampling carried out for nitrogen, carbon dioxide, and other gases with the age of the enclosing rock taken into consideration.

Use was made here of gas-logging data and stratum-testing results for 85 holes drilled at 24 deposits and exploration areas in the U. S. S. R.

In spite of the great diversity of cases considered in compiling the graph, the diminution of rock saturation with nitrogen as the age of the investigated strata increases can be clearly traced on the basis of gas-logging data. Whereas in Neogene rocks the mean nitrogen content is 57 cm³ per liter, it is equal to 28 cm³ per liter in Cambrian rocks.

A different character of nitrogen distribution as a function of geochronological data was obtained as a result of evaluation of data on the testing of gas and oil strata and gas- and water-bearing horizons. In this case the maximum nitrogen content is observed in productive Devonian, Carboniferous, and Permian strata, and the minimum content in Paleogene strata. The relation of the percentage content of nitrogen in productive strata to that of the enclosing rock can apparently be used as an indicator of the overall gas permeability of individual series (figure 1).

The distribution character of mean concentrations of hydrocarbons, carbon dioxide, and

hydrogen as a function of rock age is determined, on the basis of gas-logging data, by the geochemical features of these gases. In particular, it is found that hydrogen occurs most of all in the Paleozoic complex of deposits, as well as in other sections of shallow-bedded crystalline rock.

According to analysis of the data for natural gases, the distribution curves of heavy hydrocarbons manifest a reduction in the concentration of ethane, propane, and the other methane homologues as one passes from the more ancient Paleozoic strata (Devonian, Carboniferous, Permian) to Triassic and Jurassic deposits. Here the highest content of heavy hydrocarbons is to be found in Devonian

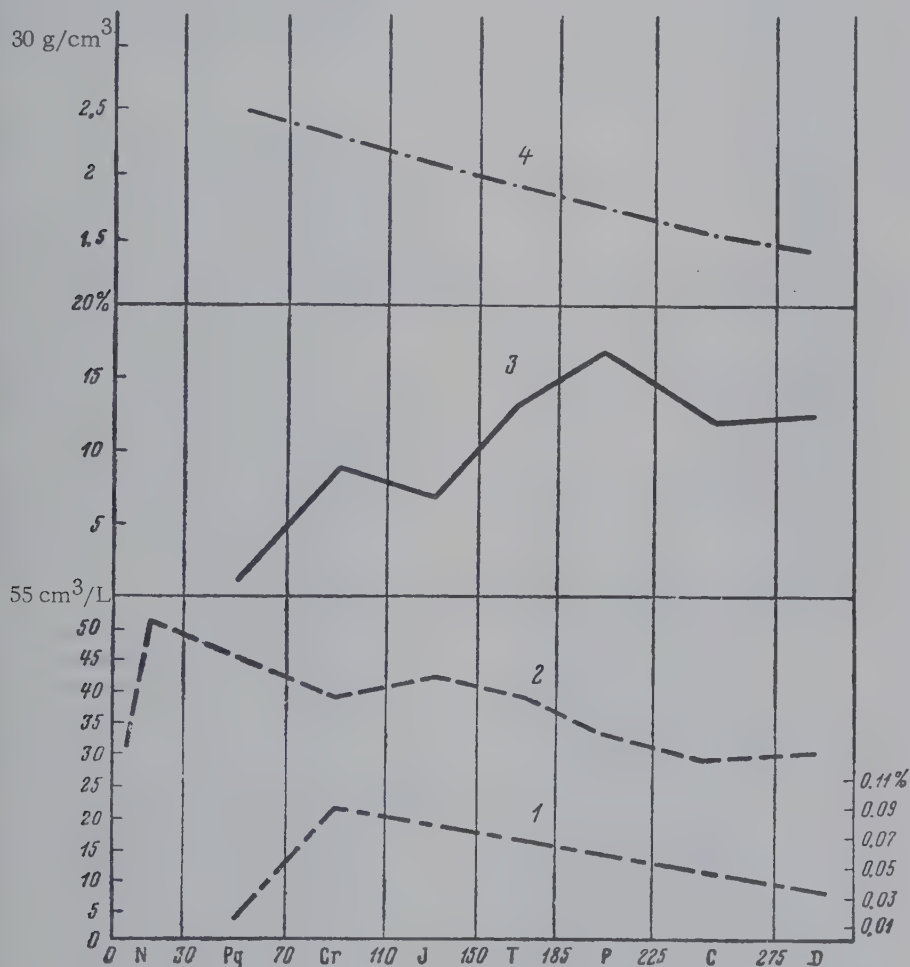


FIGURE 1. Graph of the mean content of gaseous nitrogen in gas and oil strata

Mean content

1 - organic nitrogen in rock (percent)

3 - gaseous nitrogen in oil and gas deposits (percent)

2 - gaseous nitrogen according to gas-logging data

4 - rock porosity (in g/cm)

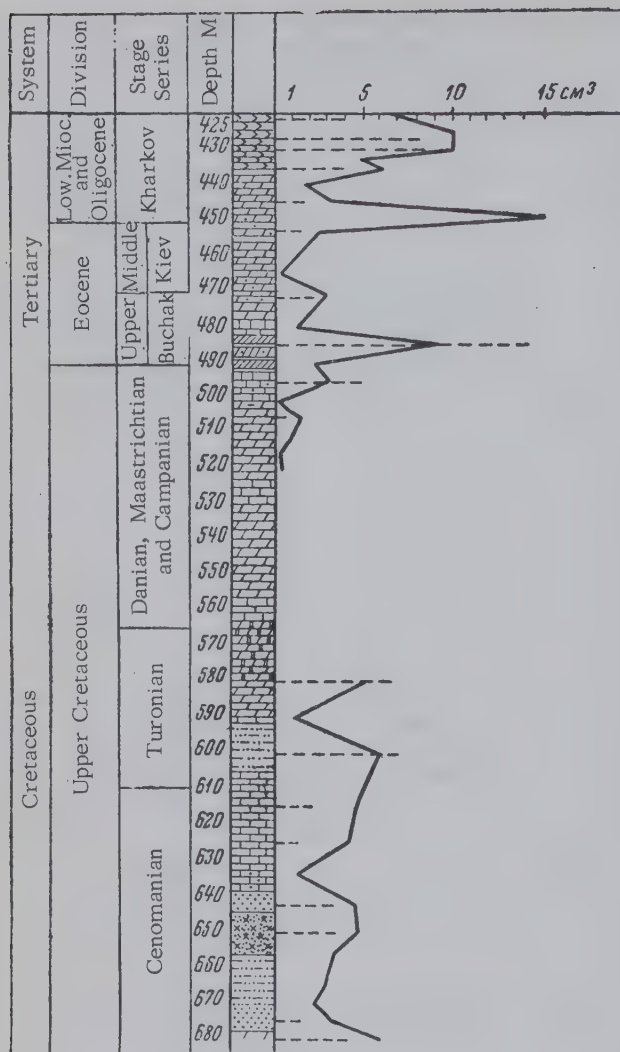
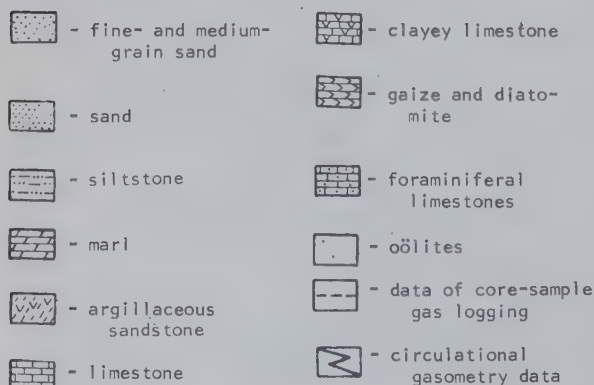


FIGURE 2. Diagram comparing the indicators of drilling-mud gas logging and core-sample gas logging (Hole R-1, Stepanovka Village)



rocks. An analogous rule is evident with respect to the upper part of Mesozoic deposits and the Cenozoic rock complex, where the maximum heavy-hydrocarbon content is attributable to productive Cretaceous strata.

Taking into consideration the actual character of the distribution of oil and gas pools in Paleozoic deposits of the Volga-Urals oblast and the Mesozoic-Cenozoic profile of the Caucasus area, it is possible to establish a general reduction in the concentrations of heavy hydrocarbons at shallower depths. This circumstance confirms the specific gravity of ethane, propane, and other heavier gaseous homologues of methane as an indicator of the oil-bearing nature of underground formations.

Let us examine in greater detail some questions pertaining to method: Comparative results of core-sample and circulational [drilling-mud] gasometry carried out at the same holes indicate that, with the present state of the arts, the selection and desorption of core samples of rock affords no great advantages over the selection and degasification of drilling-mud samples with respect to the determination of hydrocarbon gases in a zone of shallow deposits. The same has been established, in particular, by the projects of A. K. Karpov (figure 2). In a number of localities, meanwhile, higher concentrations of hydrocarbons were obtained in the case of carbonate deposits with core-sample gasometry, than with the use of drilling mud.

Gas losses taking place in circulational gasometry are different in their nature from those occurring in core-sample gasometry and, whereas the circulational method is more easily carried out in practice and permits continuous observations to be made, when employed as the principal method it must be supplemented by selection and analysis of core samples at specific intervals of drilling.

Bulk analysis of the gases by instruments of the VTI (ORSA) type, with the simultaneous determination of methane and the heavy hydrocarbons by means of microanalysis equipment, is a necessary condition for the carrying out of circulational gasometry. In case of the simultaneous desorption of core samples, the gas extracted from them can be determined only on an instrument for microanalysis. Preliminary results

the circuational gasometry of detonation holes indicate the possibility of the use of this method for exploratory purposes without core sampling.

However, an improvement in core-sample gasometry is required for the solution of theoretical problems pertaining to an investigation of the gases contained in a sorbed and a free state in core samples of rock. It is, in particular, necessary to design a core barrel by means of which a gas sample can be extracted from the core during the drilling process.

The employment of water as an eluate alters the conditions for carrying out circuational gasometry. The overall gas saturation of the eluate is sharply reduced by virtue of a more intensive natural degasification of nitrogen. At the same time, the relative content of hydrocarbons increases.

In the case of point gas logging, a gas sample extracted from the drilling mud represents only a part of the gas mixture formed from the gases of various categories that are contained in the rock being drilled. The other part of the mixture is lost when the drilling mud is brought to the surface. The problem arises of eliminating these losses by the installation of a catchment device at the mouth of the well.

The natural degasification of eluate in the gasometry of core-drilled wells is, as a result of the short length of groove communications, less intensive than in the case of rotor- and turbine-drilled wells. Therefore, in order to increase the sensitivity of the gasometry method, partial degasification of the entire eluate should be carried for the extraction of 10 to 85% of the hydrocarbons from individual samples of eluate, 30 minutes of desorption is necessary at 40° C and a vacuum of 100 mm Hg. At a higher temperature the decomposition of bicarbonate is intensified, with the formation of CO₂.

For further development of the core-sample and circuational gasometry of core-drilled wells and the detonation holes of seismic prospecting, new analytical equipment is required possessing the prerequisite sensitivity and precision for the determination of methane, individual homologues of the heavy hydrocarbons, carbon dioxide, nitrogen, and the rare gases.

Deep degasification of the eluate must, whenever possible, be carried out by an automatic method whereby it is possible to determine its specific gas saturation. It is desirable to carry out the extraction of gases from core samples of rock within the core barrel itself, in the course of the well-drilling process, and special equipment should be developed for this purpose.

Gas logging operations in East Bashkiriya and the adjacent districts are of interest from the point of view of method. They were carried out at turbine-drilled wells within the limits of the Tuymazinskiy [Tuymazy?] oil field, as well as at seismic wells in the Bavlinskiy district along a profile traversing the Khanoverkinskaya structure. According to gas logging data for wells of the Tuymazinskiy oil field, hydrocarbon gases are detected within the limits of the first 50 or 100 meters of depth in concentrations of 0.2 to 0.5 cm² per liter of eluate.

The distribution of hydrocarbon gases along the profile of Permian and Carboniferous deposits is characterized by the presence of individual disconnected peaks of low concentrations, separated by intervals of zero and background values. When the analytical data are averaged along hundred-meter depth intervals, the differing nature of hydrocarbon distribution for crest, contour, and transcontour wells is established. The greatest gradient of concentration increase with depth is noted for wells drilled within the oil-pool line; the least such gradient is that of transcontour wells.

The principal maximum of hydrocarbon content lies in the zone of Artinskian deposits and in the top portion of Upper Carboniferous strata. Below that the hydrocarbon content gradually decreases, and subsequently increases anew as the productive strata of the Stalinogorsk horizon are approached.

Thus the closest source of hydrocarbon migration, the source responsible for the presence of these gases in deposits close to the surface, should be considered the Artinskian gas and oil pool. The distribution of averaged values of nitrogen along hundred-meter depth intervals indicates that aeration processes penetrate to a considerable depth; in this connection nitrogen-content maxima, apparently of atmospheric origin, have been noted for the very top portion of deposits of the Kazanian stage and Ufa series.

As the depth increases, the nitrogen content of rock increases until the bottom portions of Artinskian and Upper Carboniferous deposits are reached; a certain similarity is observed here in the distribution, along the profile, of nitrogen and the hydrocarbon gases. Examination of gasometry data averaged within the limits of the area examined discloses that the mean saturation of deposits with hydrogen and nitrogen gas is higher in the central part of the deposit than at the transcontour and contour sections. Also noted is a certain dependence of the mean acid-gas content on elements of the structure and on its oil-bearing nature, namely: the content of acid gases decreases in the central part of the deposit and increases beyond the oil-pool outline of a Devonian structure.

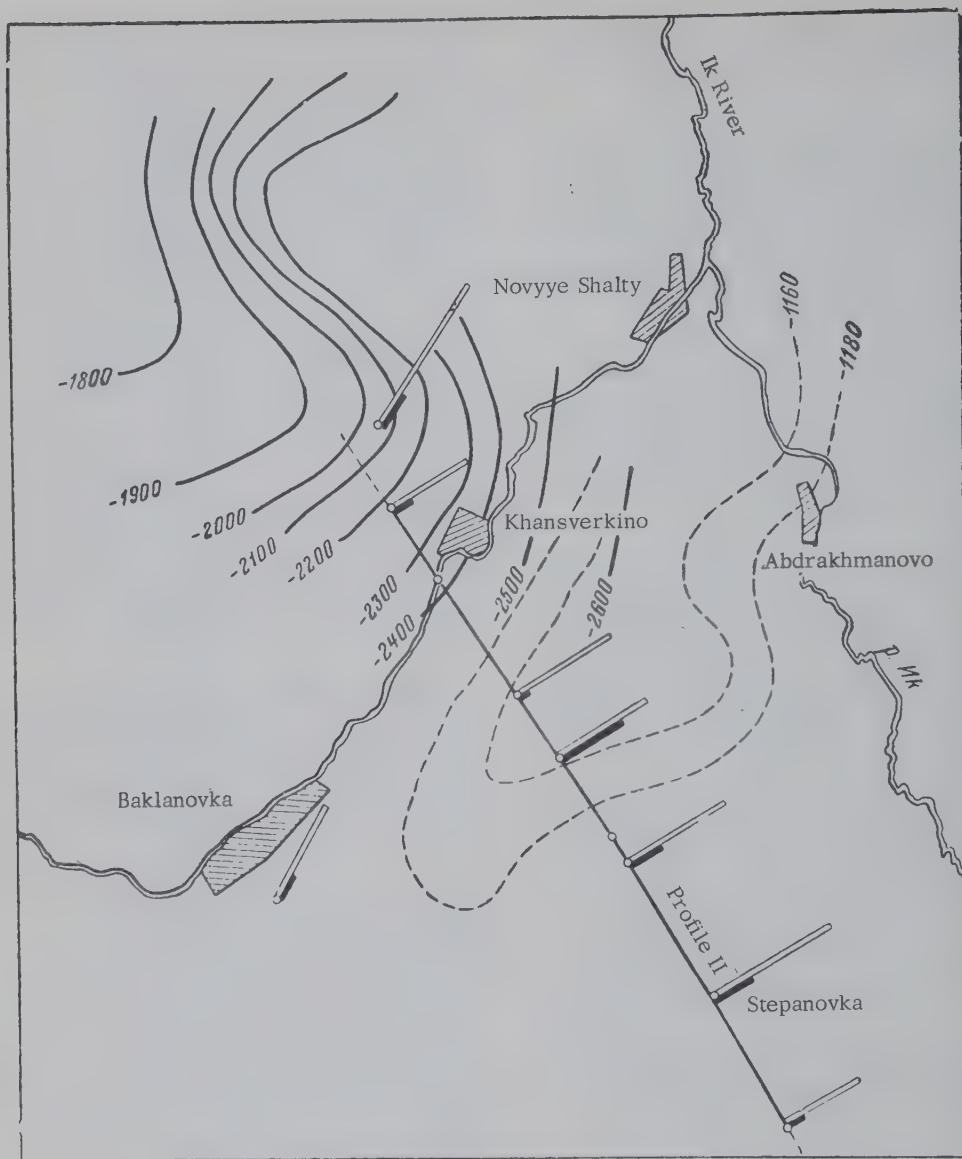
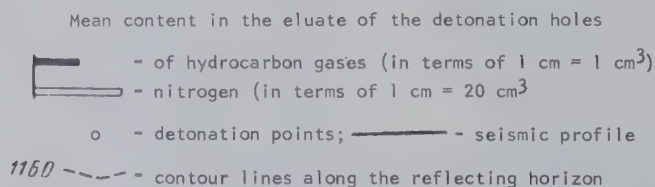


FIGURE 3. Schematic map of results of the gasometry of detonation holes along a profile traversing the Khansverkinskaya structure



The gas logging of seismic-prospecting detonation holes in the Bavlinskiy district on the Khansverkinskoye uplift (figure 3), as well as in the region of the Yefremovo-Zykovskaya structure (Orenburskaya oblast), has shown that in spite of the small depth of the drilling

operations (up to 50 m), the analysis of gas extracted from the eluate yields a maximum hydrocarbon content above uplift crests, and a maximum nitrogen content above the flanks of the uplifts; this indicates that operations of this type are suitable for practical application in

the region of Tatariya, Bashkiriya, and in the Orenburgskaya oblast, as well as in other districts of the Urals-Volga Province.

In conclusion, we consider gas logging in already-drilled wells. The possibility of such operations being performed during the process of well widening and overhaul was substantiated and demonstrated by the author, jointly with A. K. Karpov and other researchers, as far back as 1949. Later projects, carried out to test the method of subsequent gas logging in the regions of the Orenburgskaya oblast (Z. G. Georgiyev), the Komi ASSR (V. I. Sheptunov), and the Saratov district (L. M. Chekalin), confirm the practical value of this version of the method. Subsequent gas logging is already now making it possible considerably to increase the scale and reduce the cost of the operations in

progress. The results of subsequent gas logging yield highly valuable material for study of the conditions and mechanism of the filtration of fluids through the well wall into the eluate.

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THE DETERMINATION OF GROUND-WATER DISCHARGE IN ALLUVIAL DEPOSITS¹

by

N.N. Bindeman²

REVIEWER'S NOTE

Good - conclusions still depend on correct determination of "coefficient of filtration."

ABSTRACT

The ground water recharge of a river can be measured along a line at right angles to the river and expressed by the formula $q = kmik$ where q is the volume, k the coefficient of filtration, m the factor of the alluvium, and i the river gradient. Derivation of the formula is given. --M. Russell.

* * *

The determination of ground-water flow discharge in alluvial deposits of river valleys is of scientific and practical importance in the evaluation of ground recharging of rivers as well as of the natural flow discharge of ground waters.

Let us examine the simplest, most widespread scheme (see fig. 1). The river runs in a straight direction and the width of the alluvial

deposits is practically constant. The contours of the water table of the ground stream of the river under drainage are oriented in a certain sharp angle to the river. In the case where the gradient of the river is very small, which is characteristic of rivers on broad plains, the contours of the water table parallel the river. Another extreme case where the contours of the water table are at right angles to the river is possible, if the bedrock are impermeable and if the longitudinal gradient of the valley is considerable. In this case the flow of ground waters parallels the river.

Thus, the direction of ground-water flow depends upon two factors: on the volume of flow from the sides and on the longitudinal gradient of the river.

In Figure 1 the value of ground recharge of the river per shore length unit on section B_1-B is to be determined. In order to simplify the deduction we shall consider the alluvial waters as head-waters.

Let us designate the heads in point A with H , in point B_1 with H_1 , in point B with H_2 , etc. I - gradient of the river; i - gradient of the ground flow; i_k - apparent gradient of the ground flow in a direction at right angle to the river, that is: along the line $A-B_1$. The rest of the designations are shown on Figure 1.

Discharge of the ground flow per shore length unit is:

$$q = \frac{Q}{L} = \frac{kmboi}{L}, \quad (1)$$

where Q - is the volume of ground-water flow to the river on section of L length; K - coefficient of filtration; m - magnitude of the alluvium; b_0 - width of the stream;

if $b_0 = L \sin \alpha$,

then $q = kmi \sin \alpha$, (2)

where α - is the angle formed by the line of ground-water flow with the river shore.

By expressing the gradient of the ground flow through heads, we designate:

$$i = \frac{H - H_2}{l}. \quad (3)$$

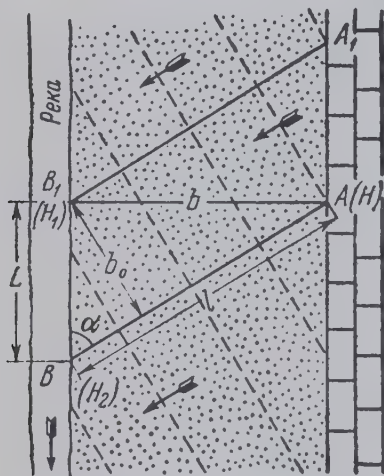






FIGURE 1. Scheme of the movement of underground waters in alluvial deposits

-  - bedrock
-  - alluvial deposits
-  - equipotentials
-  - direction of the stream lines.

¹ Translated from: Koprédeleniyu raskhoda gruntovykh vod v alluvial'nykh otlozheniyakh, Sovetskaya Geologiya, no. 6, 1960, pp. 137-139.

² All-Union Scientific Research Institute of Hydrogeology and Engineering Geology.

The head is point B(H₂) we define by the value of the river gradient

$$H_2 = H_1 - IL. \quad (4)$$

Figure 1 makes it clear that $L = 1 \cos \alpha$. If we put this definition in the equation (4) and further in equation (3), we obtain

$$i = \frac{H - H_1}{1} + I \cos \alpha. \quad (5)$$

The apparent gradient of the range AB₁ is expressed:

$$i_k = \frac{H - H_1}{b} = \frac{H - H_1}{1 \sin \alpha}, \quad (6)$$

thus,

$$\frac{H - H_1}{1} = i_k \sin \alpha.$$

By putting the definition (6) in the equation (5) we get:

$$i = i_k \sin \alpha + I \cos \alpha. \quad (7)$$

In order to find the maximum of function, we shall differentiate the definition (7) and equate the first derivative to zero

$$i_k \cos \alpha - I \sin \alpha = 0.$$

Thus, we find $\frac{i_k}{I} = \frac{\sin \alpha}{\cos \alpha} = \tan \alpha$ (8)

As we know, between trigonometric values are the following correlations:

$$\sin \alpha = \frac{\tan \alpha}{\sqrt{1 + \tan^2 \alpha}}$$

$$\cos \alpha = \frac{1}{\sqrt{1 + \tan^2 \alpha}}$$

Putting these definitions in equation (7) and substituting $\tan \alpha$ according to formula (8) we get:

$$i = \sqrt{I^2 + i_k^2}. \quad (9)$$

Using formula (8) we define also $\sin \alpha$ through the apparent grade of the ground stream and the gradient of the river.

$$\sin \alpha = \frac{\tan \alpha}{\sqrt{1 + \tan^2 \alpha}} = \frac{i_k}{\sqrt{I^2 + i_k^2}} = \frac{i_k}{i}. \quad (10)$$

Substituting definition (10) in formula (2) we finally obtain:

$$q = km i_k. \quad (11)$$

Formula (11) shows that the ground recharge of the river can be determined along a line at right angles to the river regardless of the di-

rection of the ground flow in the alluvium.

The discharge of ground waters per stream width unit in the profile which coincides with the water table, is defined by the equation:

$$q_1 = km i \quad (12)$$

or, defining the natural gradient of the underground stream according to (9) we get:

$$q_1 = km \sqrt{I^2 + i_k^2}. \quad (13)$$

The study of the problem of defining the stream discharge of ground waters in the alluvium along a line which cuts the valley at right angles to the river follows.

The discharge of the ground flow, running through AB₁ is defined by the equation:

$$Q = km b_0 i = km b i \cos \alpha, \quad (14)$$

where b is the length of the AB₁ range.

Let us define $\cos \alpha$ through $\tan \alpha$ and use the equation (8):

$$\cos \alpha = \frac{1}{\sqrt{1 + \tan^2 \alpha}} = \frac{1}{\sqrt{1 + \left(\frac{i_k}{I}\right)^2}}. \quad (15)$$

Substituting in equation (12) i according to formula (9) and $\cos \alpha$ according to definition (15) we finally obtain:

$$Q = km b I. \quad (16)$$

Thus, the discharge of ground waters along a line, cutting the valley at right angles to the river, is defined only by the latitudinal grade of the river, but does not depend on the natural grade of the ground-water flow.

DEDUCTIONS

1) In the valley sections, where the river flows more or less in a straight line and parallel to the radical shore, and the geological alluvium structure in the plane is monotypic, the ground recharge of the river can be defined by formula (11) along a line at right angles to the river, regard less of the natural direction of the stream and its grade; the discharge of the ground flow passing along this line does not depend upon the natural grade of this flow but only upon the gradient of the river, as formula (16) shows the discharge of the river per unit width passing through the section which coincides with the contour of water table can also be defined by the apparent grade of the stream and the gradient of the river, using formula (13).

2) The deductions made from the analysis of the stream movement under pressure stay the same also for streams without head. Using

the rule of transition from a head stream to a headless one, we must in this case, take for "m" the arithmetical mean value of the magnitude of the stream at the river and on the border of the radical shore.

3) These observations show that, in a number of cases, the drawing of maps of the contour water table is unnecessary. It is sufficient to drill a row of wells along a line at right angles to the river and to know the river grade.

Review Section

Gubin, Igor' E. *Zakonomernosti seysmicheskikh proyavleniy na territorii Tadzhikistana (Geologiya i seysmichnost')* [REGULARITIES OF SEISMIC PHENOMENA IN THE TERRITORY OF TADJIKISTAN (GEOLOGY AND SEISMICITY)]; Moscow, Akad. Nauk SSSR, 464 p., 1960.
A Review by Anatol J. Shneiderov.

This is a treatise on seismic regionization [provinces?] based on field studies of geology and seismicity of Tajikistan, carried out by the author and his staff under the auspices of the All-Union Scientific Exploration Geological Institute of the Ministry of Geology and Conservation of Mineral Resources of the U. S. S. R. (1931-1936); Tadjik Filial of the U. S. S. R. Academy of Sci. (1936-1945); and the Institute of the Physics of the Earth, U. S. S. R. (1945-1956). The publication of these extensive studies and research in the field and specialized literature (a bibliography of 527 Russian and 11 West-European titles is given) was undertaken to comply with the policies proclaimed by the State Committee of the Soviet of Ministers of the U. S. S. R. on Building Affairs in their "Norms and Regulations for Building in Seismic Regions" (1957). The action of the Committee has resulted in the government expenditure of several hundred million roubles for the antiseismic measures in the building industry annually.

The norm map of seismic regionization, appended to the above-named "Norms and regulations," is used in the U. S. S. R. for determination of intensities of earthquakes that may occur in the future within a given area. The seismic regions in this map are subdivided into zones of shocks of 9, 8, 7, 6, and 5 intensity points for the earthquakes expected in the zone. No other characteristics of the zone's seismicity, such as the exact locations of earthquakes, their frequencies, and other data are given, although the zone may be many thousand square miles in area. Due to this lack of necessary information, and because many strong earthquakes of the last 10-15 years did not comply with the data of the norm seismicity maps, it was necessary not only to improve the regionization boundaries on these maps, but to investigate whether or not the basis and the method of their preparation was sufficiently scientific.

Having determined that the seismostatistical data available are insufficient to characterize the seismic conditions of the U. S. S. R., and that a mechanical generalization used in preparation of the norm maps of 1940, 1949, and 1951 often distorts the general view of actual seismic conditions, the author raises a

question on the methods and basic assumptions of seismic regionization used in preparation of the norm maps. He proposes to supplement the seismostatistical data with the results of an actual (explicable) analysis of specific geological and geomorphological data obtained both by geological and geophysical methods, thus preparing the seismic regionization maps on the data of geologic conditions that result usually in earthquakes, rather than to base the regionization on a mechanical grouping of earthquakes into areas of equal intensity.

In agreement with this point of view Gubin proposes a new type of seismic regionization map. In contrast to the above-mentioned norm seismicity maps, the new maps must show the specific seismicogenic (or epicentral) zones, that is, the probable locations (sources) of earthquakes possible in the future, but not the vast areas of seismic shocks of expected intensity. Further, this new map must show the estimated maximum intensity of these expected earthquakes in a given zone, the area affected by the shocks, frequency of their occurrence and the depth of foci. It must also show the aseismogenic areas within the seismic zones. By doing this a considerable differentiation of the territory studied can be achieved.

Such a seismotectonic map must be accompanied by a legend in which the basis for establishing each separate seismicogenic zone and its degree of seismicity must be given. In other words, it must be explained why one region is assigned to a 9-point intensity zone, and the other one — to a 7-point zone; what was the method by which the frequency of earthquakes occurrence was determined, etc.

The seismicogenic zones shown on the seismotectonic maps correspond to established tectonic zones where movements that could produce future earthquakes take place. The intensity of these shocks in the future, their magnitude according to M scale, the expected areas affected, the depth of their foci, and the frequency of recurrence in different zones are determined from seismo-statistical data, the probable relative velocity of movements of the formations, the types of the latter, and the lengths as well as size of ruptures.

The various characteristics of possible earthquakes established in this way for a certain area from a large amount of seismo-statistical and geological data are extrapolated within the boundaries of equal geologic conditions.

This method of preparation of new types of maps is called seismotectonical, since it is

based on seismic and geologic data.

The seismotectonic method of seismic regionization consists of initial assumptions and of investigations and procedures required by the assumptions.

These basic assumptions were derived from the seismic phenomena empirically correlated with tectonic processes largely in central Asia. The assumptions are as follows:

1) Earthquakes result from movements of geologic structures along faults exposed on the surface, or deep in the earth, located in certain tectonic zones, mostly at the contact of structures. Frequency and the area affected by seismic shocks depend mainly upon the velocity of movement, its size (also the size of the source rupture), its depth, and the strength of the rocks disturbed.

2) Formations of different type and different stages of development have unequal degrees of consolidation, and different velocities of movement, and their source fractures differ in size and depth. Consequently, the earthquakes that occur in them are different in frequency, intensity, depth of focus, and area affected.

3) The present-day differentiated tectonic movements progress unevenly; however, in general they follow an inherited pattern of Quaternary and earlier movements, and they will move in this way with no significant changes for centuries to come. The regularities and the degree of intensity of a tectonic process govern the regularities and intensity of seismic phenomena. The latter can be understood from studies of tectonic movements.

In agreement with these basic assumptions, the geology and geomorphology must be studied in order to determine the basic geologic structures, their types, contact zones and their characteristics (the fissures of Quaternary dislocations, their size, amplitude, and probable depth), and the movement velocities of formations in the fault plane.

Then, all the instrumental and non-instrumental seismostatistical data must be collected, synthesized, and correlated with geological and morphological data in order to clarify the probable conditions for occurrence of earthquakes. At this stage the regularities in the tectonic movements and seismicity are ascertained, particularly the correspondence of earthquakes of certain intensity, their areas, and the frequency of their occurrence to certain definite structures at different stages of development.

Taking into consideration the geological data, and the conditions established for earthquakes to occur, seismogenic zones are determined and designated on the map. Various

characteristics of maximum-intensity earthquakes that may occur in these zones are added. The seismicity rating for certain areas of tectonic zones established from sufficient seismic and tectonic data is then extrapolated into the areas of identical geologic conditions.

The conditions under which the seismotectonic method of regionization can be applied to the regions of different geologic structure are dissimilar. Therefore, every area studied must, first of all, be checked for the applicability of the basic assumptions of the method to the specific local conditions, and these assumptions are modified and amplified with new data when found necessary.

The geologic structure in some regions can be determined by geological methods. In other regions various structural geophysical methods of prospecting, drilling, and seismological studies may be required for tracing faults. The available seismostatistical data may be sufficient for some regions, while in other regions local instrumental seismological investigations and repeated geodetic measurements may be needed.

Different results may be obtained by the seismotectonic method applied to different regions, depending on the geologic structure and the amount of seismostatistical material available. Conclusions on some seismogenic zones may be sufficiently definite, while for some others the data may be only tentative or cannot be obtained at all. Only the seismostatistical data could be used in the latter case. The seismogenic zones may be of different lengths and widths, and have aseismic areas within them.

In general, this monograph demonstrates the relationship of earthquakes and faults—differentiated movements of geologic structures. The attempt is made to develop the seismotectonic method, indicating its applicability and efficiency in seismic regionization of continental areas. The territory of Tadzhikistan, as one of varied geologic and seismic conditions, is treated as an example.

The book consists of four parts. In the first two the geologic structures and the seismostatistical data on Tadzhikistan are given; in the third the geology and seismicity of the region are compared, and the regularities of seismic phenomena, determined by conditions of structural developments, are established; and in the fourth part the seismic regionization of Tajikistan and the basis for such a regionization, are presented, taking the data of the latest geological and seismic investigations into account.

A classification of earthquakes according to their connections with different geologic

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structures is given as Chapter 2 of Part 3. This classification was used in describing the intensity and the type of earthquakes for each zone in the seismic regionization map prepared by I. E. Gubin.

Sixteen destructive and medium-intensity earthquakes have occurred in Tajikistan in the period from 1947 to 1960. All of them occurred in the zones designated on the map as highly active, the strongest shocks in each affected area were of the type and intensity predicted. Of the sixteen, four earthquakes occurred in the zones generally recognized as highly active seismically. The remaining 12 occurred in the zones where no shocks were recorded seismostatistically. These 12 are therefore considered as predicted by the seismotectonic method proposed.

Nalivkin, Dimitri Vasil'evich, STUDY OF FACIES, GEOGRAPHIC CONDITIONS OF FORMATIONS OF SEDIMENTS¹, in two volumes, 1956. A Review by Siemon W. Muller, Stanford University.

EDITOR'S NOTE

D. V. Nalivkin's two-volume work, Study of Facies, was chosen for publication in full under the translation program of the American Geological Institute. Early reviewers of the nearly completed manuscript recommended against publishing the work in its complete form. In the September 1960 issue of International Geology Review, the translated first chapter of Volume I was published (IGR, v. 2, no. 9, p. 772-780).

The English translation is now complete and copies of the unedited manuscript are available from the AGI Translations Office, in whole or in part. Details for ordering and a complete table of contents of the work are given at the end of this review. In addition to the English translation, a French translation (Etude des facies) is available from the Service d'information geologique du B. R. G. G. M. (74, rue de la Federation, Paris, France).

Dr. Siemon W. Muller, member of AGI's Translations Committee, has provided the following reviewers' notes on the work. . . M. R.

* * *

The two volumes of Nalivkin's Study of Facies, 1956, totalling 926 pages, perhaps

should be more appropriately entitled "The Study of Sediments." The work is essentially a compilation with a few original ideas and it may be open to question if the publication of the translation of the entire work is warranted.

The concept of facies in the U. S. S. R. is defined in many different ways by different workers so that no single definition reflects the attitude of all the Russian stratigraphers. The translation of Chapter I of Volume I, as published in International Geology Review in September 1960, should carry the reservation that it is only a view of Nalivkin and that it is not shared by the majority of Russian geologists.

The second chapter, entitled "Accumulation of Sediments," presents a basic relationship of sediments to the movement of water and the tectonic action of the earth's crust. The chapter includes the discussion of stratification, definitions of different bedding planes, rhythmic sediments, cross bedding and submarine sliding. Surface markings on sedimentary layers are discussed in Chapter III. They are divided into four groups:

- 1) The markings which are formed above the sea level.
- 2) The markings which are produced in a tidal zone.
- 3) The markings which are formed below the tidal zone.
- 4) Miscellaneous markings.

The chapter also includes a brief description of concretions, spherulites, oolites, and stylo-lites. In this chapter the sediments are also analyzed with respect to the porosity and color.

The types of the most important sediments are briefly treated in Chapter IV.

The "formation sea" with its subdivisions of shelf, beach, reefs, submarine canyons, sea mounts, etc., is treated in Chapter V. A considerable amount of space is devoted to the discussion of lagoons and reefs.

The compilation of the first volume is based, to a considerable extent, on the original works by the leading American and western European sedimentologists as can be seen from the 40 pages of bibliography given at the end of Volume I.

The second volume of 393 pages discusses the "formation continent." The first chapter is devoted to the sediments and faunas in the different lakes, swamps, and playas. It also includes the discussion of river valleys, volcanic debris, and sand dunes. Some space is devoted to the discussion of karst.

Ucheniye o Fatsiyakh; Geograficheskiye usloviya obrazovaniya osadkov: Akademiya nauk SSSR, Otdelenie geologo-geograficheskikh nauk, Moskva-Leningrad, 2 vols., 1956; v. 1, 533 p.; v. 2, 393 p.

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The continental "Nimias" are recognized as consisting of: 1) delta; 2) coastal plain, 3) desert, 4) foothills of the mountains, 5) mountain ranges, 6) peneplains. The types of deposits in each of the above "Nimias" constitute the second half of the first chapter.

The methodical instructions to determine the condition of the formation of deposits con-

stitute the subject of Chapter II. This chapter includes the criteria which enable one to distinguish marine deposits from continental and gives a general idea on the characteristics to determine the depth of water, the climatic conditions and the salinity of water. In the bibliography of 22 pages at least a third of the references are to western European and American sources. --S. M.

* * *

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- Use of hydrochemical methods in prospecting for copper ores in Uchaly District. V. F. Kovalev and others. pp. 93-109.
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- Expansion of research on applied geophysics. p. 99.
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- Determining seismic districts of the Crimea. S. L. Solov'ev. pp. 110-111.
- Problems in the mechanical breakdown of rocks. L. I. Baron. pp. 114-116.
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REFERENCE SECTION

RECENT TRANSLATIONS IN GEOLOGY A Review of the Translations Services

Compiled by Amber Eustus

This part of the Reference Section is devoted each month to a listing of the new translations of geologic significance which have become available from sources other than IGR and the established cover-to-cover journals. This is done to accomplish several purposes: 1) inform geologists of the foreign literature in their fields available in translation; 2) provide information necessary to avoid duplication of translation effort, and advise geologists of the activities of the organizations providing translations or related services in their field. List includes book reviews available from Office of Technical Services, U. S. Dept. of Commerce and Special Libraries Assoc.

NATIONAL RESEARCH COUNCIL OF CANADA TRANSLATIONS

The Library of the National Research Council of Canada conducts a translation program of considerable scope and high selectivity, judging from the titles listed in Technical Translations. The Library's Translations Section shares index cards with its United States counterparts, OTS and SLA. In addition to listing newly completed translations in Technical Translations, NRCC publishes List of Technical Translations, with supplements issued every 100 titles. NRCC's program is run primarily for scientist members, but many of its translations are made available for a small charge, beginning at \$0.50 for up to 10 pages and \$0.50 for each additional 10 pages or fraction thereof.

The Canadian program differs somewhat from those of U.S. agencies with its heavy emphasis on geopedology. Besides its recently begun cover-to-cover translation of the Soviet journal Problemy Severa (Problems of the North), the NRCC covers other Soviet material on the Arctic and Antarctic region. While Russian sources are heavily drawn upon in this branch of science, the Canadians have shown less inclination to drop all other languages in favor of Russian. Their program, again judging from titles, is distributed fairly evenly among German, French, Italian, Spanish, Dutch, Swedish and Norwegian in many fields.

As Canada is officially bilingual, NRCC also translates from English to French.

The Library invites other Canadian organizations to report or deposit translations with it, offering to keep the donor anonymous, and to check its 90,000-card index to prevent duplication of effort or to help locate translation sources. It does not supply lists of translations by subject field, however.

TRANSLATIONS IN PROCESS

Recent Translations does not attempt to keep tabs on all works under translation, but, because of the great investment involved, translations of major works in process will be announced as they come to the attention.

Latest entries include:

Beus, A.A., 1956 and 1960, Geokhimiya berilliya i smekicheskoye tipy berilliyevykh mestorozhdenii (Geochemistry of beryllium and genetic types of beryllium deposits): Akad. nauk SSSR, Inst., mineralog., geokhim. i kristallo. redkikh elementov, Moscow, pp. 3-331 (1956). The Geochemical Society, working with Consultants Bureau, announces that translation of the 1956 edition is almost ready for the printer. The 1960 edition, which Earl Ingerson describes as having "a different slant," is also being translated, and the first few chapters are already under the editor's pencil.

Anonymous, 1956-1958-1960, Regional stratigraphic

graphy of China: Chung Kuo Ti Ts'en Piao (Systematic stratigraphic tables of China), Inst. of Geology, Academia Sinica, Science Press, Peiping. Translation has been started by J.E.S. Bradley of England. He is working from a combination of the original 1956 edition, the 1958 supplement, both in Chinese, and the 1960 Russian edition.

The 1962 Program for Scientific Translations announced from Israel includes two books which may be of interest to geologists: Rode, A.A., 1955, Soil science: Pochvovedeniye, pp. 1-524. Goslebumizdat, Moscow-Leningrad.

Glinka, K.D., 1931, Soil Science: Pochvovedeniye, 4th ed. Gosudarstvenn. Sel'skokhoz. izd., Moscow-Leningrad, pp. 2-612.

GEOLOGIC TRANSLATION JOURNALS

The expanding coverage of Soviet scientific literature is probably matched only by the expansion of Soviet scientific literature itself. As IGR's contribution to "keeping abreast," we publish this updated list of translations journals dealing wholly or in a large part with articles of geologic interest, together with dates of first Russian issues so covered. Those marked (*) so consistently contain articles of interest to geologists of one field or another that titles falling within the scope of the cover-to-cover translation program of these journals are not included in monthly Recent Translations listings.

Advances in Physical Sciences [Uspekhi fizicheskikh nauk]: Israel-Atomic Energy Commission, from 1957.

*Bulletin (Izvestiya), Academy of Sciences, USSR. Geophysics Series [Izvestiya, Akademiya nauk SSSR. Seriya geofizicheskaya]: American Geophysical Union, from Jan. 1957.

Cement [Tsement]: Consultants Bureau, from 1956, irregular.

*Doklady of the Academy of Sciences [Akademiya nauk SSSR. Doklady]: American Geological Institute, Geochemistry section from 1956 and geology section, from v. 112, 1957, combined with v. 124, 1959.

*Economic Geology - U.S.S.R. [Geologiya i rudnykh mestorozhdenii]: Resumes of entire journal monthly in Economic Geology, by E. A. Alexandrov, Jan. 1959.

Radiochemistry [Radiokhimiya]: Israel-Atomic Energy Commission (Ord. OTS), from 1960, v. 2.

*Soviet Geography: Review and Translation [Selected translations]: American Geographical

INTERNATIONAL GEOLOGY REVIEW

Society, from Jan. 1960, v.1, no. 1.

*Soviet Geology [Sovetskaya Geologiya]: American Geological Institute, from Jan. 1960, selected translations included in International Geology Review, beginning with v. 3, no. 10.

*Soviet Journal of Atomic Energy [Atomnaya energiya]: Consultants Bureau, from 1956.

*Soviet Physics - Crystallography [Kristallografiya]: American Institute of Physics, from Jan. 1957, v. 2.

Soviet Soil Science [Pochvovedeniye]: American Institute of Biological Sciences, from Jan. 1958.

INVITATION TO TRANSLATORS

A new and growing source of translations is geologists themselves. These are being made available to the scientific community through the AGI Translations Pool. Geologist-translators are invited to submit a copy of any papers they translate so that they can be indexed, announced and reproduced at cost (15 cents per page) by a very readable photocopy process. The manuscripts should be readable-clear carbons are acceptable -- but need not be highly polished. Submittal of a copy of a translation will be construed as an offer for IGR to publish or make copies available at cost or to consign the translation to a major repository.

The AGI Translations Pool also provides copies of those papers from Sovetskaya Geologiya not published in IGR.

Geologists are urged to submit titles of translations which have not appeared in our sources, together with information on purchase or library loan.

TRANSATOM - TRANSATLANTIC INDEX

The broadening field of nuclear research is harvesting its own translations index, Transatom Bulletin, published by EURATOM, or European Atomic Energy Community. Issues have been arriving since January's, the latest being Volume 1, Number 6. The monthly listings, which began with an obvious boost from U. S. sources, are now an equal balance of English, French and German translations largely from Russian. The topics, all relating to nuclear science, include a good number on prospecting, radioactive rock-dating techniques and analysis of minerals. The latest issue nearly equalled Technical Translations for size, despite its narrower scope.

Mailing address for subscriptions (\$8.00 regular mail; \$16.00 airmail) is EURATOM, Transatom Service, 51 rue Belliard, Brussels, Belgium. Acting director is Edward J. Brunenkant, Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C.

SOURCES OF TRANSLATIONS

The current list of recent translations is from the following:

Technical Translations, v. 6, nos. 3, 4 and 5.

Transatom Bulletin, v. 1, nos. 5 and 6.

AGI Translations Office.

An index of sources and addresses will be found at the end of the list of translations.

RECENT TRANSLATIONS

Akademiya Nauk SSSR, 1960, Atlas of the far side of the moon; formations discovered on the far side of the moon from photographs received by an automatic interplanetary station on October 7, 1959: review of a book, Atlas obratnoy storony Luny; obrazovaniya, vyyavlenyye na obratnoy storone Luny po fotografiyam poluchennym avtomaticheskoy mezhplanetnoy stantsiye 7-go oktyabrya 1959 goda, Moscow, 149 pp., 5,000 copies printed. OTS BR-SOV/5265. \$1.10

Alimov, Oleg D., et al., 1960, Boring machinery: Review of a book, Buril'nyye mashiny, Moscow, Gosgortekhnizdat, 256 pp., 5,300 copies printed. BR-SOV/5156. 2 pp. \$1.10

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Anonymous, 1961, Geological survey in North Vietnam: Jen Min Jih Pao (Chinese People's Republic) 26 Feb., p. 4. JPRS: 9416. OTS or SLA 61-23465. \$1.10

Anonymous, n.d. [1961?], Atmosphere of Venus: review of Soviet literature: AID rept. 61-30; AD-254-403. OTS or SLA 61-19631. \$1.60

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INDEX OF SOURCES

- AAAS American Association for the Advancement of Science
1414 Massachusetts Ave., N. W.
Washington 5, D. C.
- AGI AGI Translations Office
American Geological Institute
2101 Constitution Avenue, N. W.
Washington 25, D. C.
- ATS Associated Technical Services, Inc.
P. O. Box 271
East Orange, N. J.
- BISI British Iron and Steel Industry
Translation Service
The Iron and Steel Institute
4, Grosvenor Gardens
London, S. W., 1, England
- CB Consultants Bureau Enterprises, Inc.
227 West 17th Street
New York 11, N. Y.
- CEA Commissariat a l'Energie atomique
S. A. R. L. DUNOD
92, Rue Bonaparte
Paris (6^e), France
- CFC Capehart Farnsworth Corp.
Fort Wayne, Indiana
- CNRS Centre National de la recherche
scientifique
Centre de Documentation
15, Quai Anatole France
Paris 7e, France
- DSIR NLL National Lending Library
Department of Scientific and
Industrial Research
20 Chester Terrace
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Office of Technical Services U. S. Department of Commerce Washington 25, D. C.	SLA	Special Libraries Association Translations Center The John Crerar Library 86 Randolph Street Chicago 1, Illinois

INTERNATIONAL GEOLOGY REVIEW

FUTURE RUSSIAN GEOLOGIC LITERATURE

One of the major problems in covering the Russian literature is acquisition of books. Because Soviet publishers plan the number of books to print on the basis of a closely predicted audience, often by the time a work becomes well known outside the Soviet Union the supply has been exhausted. The American Geological Institute's Translations Committee has suggested the following means of helping the American geologist meet this problem. The weekly bibliographic publication *Novyye Knigi* [New Books] includes pre-publication announcements of books in many fields. The AGI Translations Office is making arrangements for systematic review of *Novyye Knigi* and subsequent translation and publication in *International Geology Review* of notices of books-in-press of potential interest to geologists. By so doing we expect to provide better information for the AGI translation program as well as to give interested scientists and librarians advance notice of pertinent works so that they may place orders with their book dealers in time to be reasonably assured of delivery.

This first list has been translated from *Novyye Knigi*, 1961, numbers 6, 7, 8, and 10, dated February 7 through March 7. When final working arrangements have been completed we expect to be able to publish notices within a month or two of receipt of the booklet.

RUSSIAN GEOLOGY IN PRESS, FROM *NOVYYE KNIGI*

1961, No. 6, February 7.

Geology and Presence of Oil and Gas in the South Part of the U. S. S. R. Fore-Caucasus Area. Gostotekhizdat. 1500 copies, 2 rubles, 80 kopecks. First quarter 1961.

Presents the characteristic features of the geologic structure and presence of oil and gas in the steppe region of the Fore-Caucasus Area, and new data on the Lias and Middle Jurassic of the northern slope of the Caucasus as well as in the adjacent part of the slope in the Central Fore-Caucasus Area; problems pertaining to the presence of and prospects for oil and gas in the Upper Lias and Middle Jurassic rocks are discussed.

Amiraslanov, A. A. and Ivanova, N. S. Lead-Zinc Deposits of Australia. Geologic characteristics and conditions governing distribution. Moscow, Gosgeoltekhizdat, 1960. 136pp. 2000 copies, 63 kopecks.

Geological Collection. Leningrad, Gostoptekhizdat, Leningrad Section, 1960. 599pp. (Transactions of the All-Union Petroleum Scientific-Research Institute, Issue No. 163). 2000 copies, 2 rubles, 97 kopecks.

Dymkov, Yu. M. Uranium Mineralization of Ore Mountains. Moscow, Atomizdat, 1960. 100pp. 3000 copies, 34 kopecks.

Zenkovich, V. P. Morphology and Dynamics of the Soviet Black Sea Coast. Vol. 2, Northwestern Part. U. S. S. R. Academy of Sciences Press, 1960, 216pp. (Institute of Oceanography). 1500 copies, 1 ruble, 20 kopecks.

Protod'yakov, M. M. Determination of the Maximum Runoff of Surface Waters from Small Basins. Leningrad, Gidrometeoizdat, 1960, 171pp. 8000 copies, 70 kopecks.

Structure and Conditions of Accumulation of the Principal Middle Carboniferous Coal-Bearing Formations and Coal Beds in the Donets Basin. Author: Yu. A. Zemchuzhnikov and others. Part Two. Moscow, U. S. S. R. Academy of Sciences Press, 1960, 347pp. (Transactions of the Geological Institute, Issue No. 15) 1400 copies, 3 rubles, 80 kopecks.

Facies and Paleogeography of Jurassic Rocks in the

Eastern Ukrainian Gas and Petroleum Basin. Author: O. D. Bilik and others. Khar'kov University Press, 1960, 73pp. (Ukrainian Affiliate of the All-Union Scientific-Research Institute of Natural Gas; Ukrainian Scientific-Research Geologic Survey Institute) 1500 copies, 36 kopecks.

1961, No. 7, February 14.

Geomorphology and Recent Tectonics. (Scientific notes of Leningrad University, No. 298). Leningrad University Press. 2000 copies, 84 kopecks. First quarter 1961.

This collection of papers is devoted to problems of geomorphology and Quaternary Geology. The Quaternary deposits of several regions of the U. S. S. R. - Karelia, the Kola Peninsula, the Azov and Black Sea coasts - and problems of the classification of relief forms are examined.

Geophysical Work in the Solution of Geological Problems in Eastern Siberia. Gostoptekhizdat, 2000 copies, 1 ruble, 60 kopecks. First quarter 1961.

This book generalizes the experience of many years of geophysical work carried out in Eastern Siberia. A description of geophysical methods of exploration used during the study of the geology of the south part of the Siberian Platform is given, as well as prospecting methods for flat, buried oil and gas bearing structures, and prospecting and exploration methods for ore deposits. For geologists and geophysicists.

Recent Information on the Stratigraphy and Tectonics of Japan. Survey. Press of the All-Union Institute of Scientific and Technical Information, Academy of Sciences of the U. S. S. R. 3000 copies, 1 ruble, 20 kopecks. First quarter 1961.

This work consists of a number of chapters dealing with tectonics and stratigraphy (from the Paleozoic to the Pliocene). Most recent data on volcanism and Recent tectonics are given.

New Data on the Quaternary Deposits of Africa. Survey. Press of the All-Union Institute of Scientific and Technical Information of the Academy of Sciences of the U. S. S. R. 3000 copies, 50 kopecks. First quarter 1961.

Data of the last 15 years on Quaternary deposits and the distribution in them of fauna and archeological

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ads, principles of subdivision and the stratigraphic system of Quaternary deposits of Africa, and a survey of indicators of climatic change in Africa are presented.

distribution of Rare Elements in the Earth's Crust. Survey. Part I. Press of the All-Union Institute of Scientific and Technical Information of the Academy of Sciences of the U. S. S. R. 3000 copies, 72 kopecks. First quarter 1961.

In this survey are examined and systematized the most recent (in the past ten years) data existing in the world literature on the distribution of rare elements and their minerals in igneous and sedimentary rocks, the weathering mantle, soils and in waters.

1961, No. 8, February 21.

Yermol'ts, G. Ya. Ammonites of Lower and Middle Jurassic Rocks in the Northern Caucasus. Leningrad University Press. 3000 copies, 1 ruble, 41 kopecks. Second quarter, 1961.

Describes ammonites occurring in rocks of Lower and Middle Jurassic age that are widely distributed on the northern slopes of the Caucasus Mountains. The monograph contains a stratigraphic summary and analysis of the principal methods for separating lower from Middle Jurassic rocks.

1961, No. 10, March 7.

Problems of Engineering Geology in the Ukrainian S. S. R. Transactions of the First Ukrainian Hydrogeological Conference. Volume II. Ukrainian Academy of Sciences Press. 1500 copies, 73 kopecks. Second quarter, 1961.

This collection of papers treats problems of regional engineering geology in the Ukrainian S. S. R., the engineering-geology mapping of relatively diverse conditions in the Ukrainian S. S. R., the study of slumping and reworking along reservoir banks, and also methodology of engineering geology investigations.

Yevseyev, S. V. Earthquakes of the Ukraine. Ukrainian Academy of Sciences Press. 1500 copies. Second quarter, 1961.

Catalog of earthquakes recorded in the Ukraine from ancient times to our own days.

Kukharensko, A. A., and Trushkova, N. N. Atlas of Placer Minerals. Gosgeoltekhizdat. 3000 copies, 2 rubles, 14 kopecks. Second quarter, 1961.

Contains pictures of heavy minerals from various regions of the Soviet Union. Most of the pictures are in color, showing the natural coloration of the minerals. The figures are printed on plates with captions which include the mineral name, its crystalline properties, locality, and magnification of the figure.

Papers on the Geology of the Quaternary Deposits of the Ukraine. Ukrainian Academy of Sciences Press. 1500 copies, 1 ruble, 46 kopecks. Second quarter 1961.

In this collection of papers, the development of relief and the formation of the Quaternary deposits in the Ukrainian S. S. R., and the boundary between the Quaternary and Neogene systems are traced. A number of articles are devoted to the mineralogical composition of Quaternary formations, and also to the geomorphology of the Carpathians and Poles'ye.

